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INTERIM REPORT

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HUGHES

HUGHES AIRCRAFT COMPANY
GROUND SYSTEMS GROUP
FULLERTON, CALIFORNIA

COLLECTION SYSTEMS

INTERIM REPORT

AUGUST 1983

Prepared Under Contract To
THE CENTRAL INTELLIGENCE AGENCY
DEPUTY DIRECTOR FOR INTELLIGENCE
OFFICE OF SCIENTIFIC AND WEAPONS RESEARCH

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Central Intelligence Agency
Office of the Deputy Director for Intelligence

9 November 1983

22 NOV 1983

NOTE TO: Director of Central Intelligence

FROM : Deputy Director for Intelligence

SUBJECT: Hughes Study on Collection Systems

Attached is the study we have been discussing. I have outlined some key points in the first dozen pages and call your attention to further highlighting on pages 17, 33, 59, 71, 78, and 92. The summary is useless.

One point brought out in my briefing out west, that I did not find in the report is that in assessing alternative collection systems you would select a half dozen or so samples like the surface to air missile sample discussed in the study to give you a feel for comparative advantages of systems in diverse areas. For example, you might want to look at a particular economic target, two or three other kinds of military targets and perhaps a political-military target to give you a relative sense of the advantages and disadvantages of each of the candid collection systems. You obviously cannot apply this cumbersome methodology to all possible targets. Sampling would be required.

I should caution again that Hughes acknowledges more work remains to be done on this, ~~and~~ that it is cumbersome and time consuming, and my impression is that they are continuing this work.

- RG.

COLLECTION SYSTEMS

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FOREWORD

This interim report was prepared by the Hughes Aircraft Company, Fullerton, California under contract 82-N7880000. The prinicipal Hughes analysts for this effort have been Ms. K.J. Baldasari, Mr. R.S. McKinnell, and Mr. W. Lund.

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I. PROBLEM STATEMENT

PROBLEM STATEMENT

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- DEVELOP A METHODOLOGY TO PERFORM UTILITY ASSESSMENTS OF COLLECTION CONCEPTS
  - THE METHODOLOGY SHOULD BE CAPABLE OF DEALING WITH THE ENTIRE CONCEPT LIFE CYCLE
- RELATE THE METHODOLOGY TO SPECIFIC INTELLIGENCE QUESTIONS

The purpose of this effort is to develop a methodology to assess the utility and capabilities of collection system concepts. Such a methodology is needed to bring a systematic procedure to a process which has heretofore been intuitive and variable.

The methodology developed must be flexible, enabling it to be applied to the wide range of concerns and problems with which collection systems must deal. The final task of this project therefore is to show the developed methodology's flexibility and adaptability by applying the outlined procedures to a mutually agreed upon problem, assessing the information required to determine the impact of a new surface-to-air missile (SAM) on the balance of power.

METHODOLOGY OBJECTIVES

HUGHES

- DEVELOP A STANDARDIZED PROCEDURE FOR ASSESSING COLLECTION TECHNIQUES AND STRATEGIES
  - STRUCTURALLY INDEPENDENT OF PROBLEM TYPE
  - HANDLE MULTI-OBJECTIVE, MULTI-FACTOR DECISIONS
- GENERATE UNIQUE, TRACEABLE PATHS FROM PROBLEM ELEMENTS THROUGH INFORMATION REQUIREMENTS TO APPLICABLE COLLECTION TECHNIQUES
  - METHODOLOGY SHOULD DEVELOP A MEANS TO FOCUS ON SIGNIFICANT ISSUES, SCAN THE LESS SIGNIFICANT, ELIMINATE THE IRRELEVANT
- INCORPORATE MULTI-FACETED TYPES OF DATA AND INFORMATION
  - COMBINE QUALITATIVE AND QUANTITATIVE MEASURES OF EFFECTIVENESS
  - INCORPORATE UNCERTAINTY IN PARAMETER QUANTIFICATION
  - ALLOW FOR EASY INCORPORATON OF ADDITIONAL INFORMATION
  - AGGREGATE EXPERT OPINIONS

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The first step in methodology delineation involved documenting objectives the methods employed should satisfy. The overriding objective was to develop an approach which would replace the intuitive methods employed in the past with techniques which are auditable, generate traceable analysis paths and are valid over time.

The need for a standardized procedure is especially acute given the diverse nature of problems to be addressed and the multi-faceted decisions to be reached. The methodology should highlight the critical decision components in an easy manner and allow for analysis review and sensitivity testing.

A complicating factor in the problem is the diverse nature of the data used in collection analysis. The data tends to range from being highly qualitative, such a the doctrine of the enemy, to the highly quantitative, such as the physical number of systems to be deployed. Additionally, the collectibility of required information is not a guaranteed event, but instead is uncertain and possesses a probability distribution whose form may depend upon the expert performing the analysis or formulating the question. Furthermore, the data employed does not remain constant, but instead is dynamic and depends upon the timing of the analysis and its requirement. Therefore, to reflect this diversity the methodology should be adaptable to reapplication and easily incorporate additional information as it becomes available.

DECISION ANALYSIS

HUGHES

DECISION ANALYSIS COUPLES THE QUANTITATIVE TECHNIQUES OF SYSTEMS ANALYSIS WITH THE QUALITATIVE THEORIES OF DECISION THEORY

DECISION ANALYSIS IS SUITED TO PROBLEMS CHARACTERIZED BY

- UNCERTAINTY
- COMPLEX PREFERENCES
- IMPORTANCE
- UNIQUENESS
- LONG RUN IMPLICATIONS

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Decision analysis refers to a body of knowledge and techniques which combines decision theory and system analysis. Decision theory investigates the manner in which people assemble information to make decisions and the actual decision making process. System analysis brings to the effort techniques for problem decomposition, handling uncertainty in parameters, and mathematical decision rules.

The combination of these two disciplines is ideally suited to the collection systems problem since it allows for uncertainty in parameter evaluation, can handle complex problems through decomposition, and provides a systematic framework for evaluation. Decision analysis is not appropriate for smaller problems as the effort of analysis may be too large for less significant issues. Therefore, the techniques are most appropriate when the issues under study are complex, of relative importance, unique and identifiable, and the long-run implications are such that a temporarilly stable method of review is desirable.

SUCCESSFUL DECISION ANALYSIS APPLICATIONS

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- VOYAGER SPACE PROJECT
- NUCLEAR POWER PLANT SITE SELECTION
- URBAN DEVELOPMENT
- FEDERAL ENERGY POLICY
- CORPORATE INVESTMENT POLICY
- DAM SITE SELECTION

Decision analysis is a proven, developed approach through which decisions have been made. Decision analysis has been applied on projects ranging from the highly quantitative Voyager Space Project to the qualitative concerns of urban development. The broad range of successful applications illustrates the flexibility of the method as well as its maturity.

Selection decisions have been made successfully using these techniques. By its very nature, decision analysis is well suited to comparing alternatives and making incremental assessments.

DECISION ANALYSIS: THE PRO'S

HUGHES

- THE DECISION MAKER IS ENCOURAGED TO SCRUNTINIZE THE PROBLEM AS AN ORGANIC WHOLE
- ALLOWS EACH EXPERT TO GIVE TESTIMONY ABOUT A PARTICULAR AREA OF EXPERTISE IN AN UNAMBIGUOUS, QUANTITATIVE MANNER THAT CAN BE INTEGRATED INTO THE OVERALL ANALYSIS
- ALLOWS THE DISTINGUISHING OF THE DECISION MAKER'S PREFERENCES FOR CONSEQUENCES FROM JUDGEMENTS ABOUT UNCERTAINTIES
- CAN BE USED TO CLEARLY COMMUNICATE THE RATIONALE FOR THE ADOPTED STRATEGY AND RALLY SUPPORT FOR IT
- CLEARLY POINTS OUT THE FACTORS INCORPORATED INTO THE ANALYSIS
- ALLOWS FOR THE DECOMPOSITION OF THE PROBLEM INTO ITS BASIC PARTS SO ISSUES WHERE THERE ARE FUNDAMENTAL DISAGREEMENTS CAN BE EXPOSED
- MAY REVEAL PREVIOUSLY HIDDEN RELATIONSHIPS/STRUCTURE

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Decision analysis brings several advantages to a collection system analysis. The techniques encourage separation of the factors and basis of the decision from the personal biases and feelings of the decision maker. Additionally, structure is introduced to the problem which allows for easier communication of ideas and improved analysis possibilities. The framework is such that sensitivity analysis is possible. Under the intuitive methods of the past such analysis of variance was not possible.

Decision analysis makes complex problems easier because decomposition into smaller problem pieces is possible. Decomposition allows those most capable of performing a subtask to do so without also requiring performance outside any areas of expertise. Synergy will result when the pooled opinions of these experts are generated which will lead to a better basis for reaching decisions than otherwise would have been available.

DECISION ANALYSIS: THE CON'S

HUGHES

- DECISION ANALYSIS DOES NOT REPLACE OR LESSEN THE VALUE OF THE EXPERT'S OPINION
- THE DEVELOPED METHODOLOGY DOES NOT ENSURE ALL PROBLEM ELEMENTS ARE CONSIDERED

While decision analysis offers many advantages, the methodology is not without its weaknesses. As with any technique, these limitations need to be recognized going into a task so their potential effects can be minimized. The first limitation of decision analysis is it will still require input from personnel knowledgeable about the subject matter. The methodology will not serve as a substitute for knowledge or experience, but the method will take whatever expertise is available and make optimal use of the information.

The developed methodology also does not ensure all problem elements are automatically considered. Missing elements will occur since the problem is structured from the ground up and omissions are possible. These omissions are, however, easily corrected later in the analysis when they are discovered. This weakness also points to the need to have a "pool" of experts work on the problem to assure full coverage of problem issues.

METHODOLOGY CHOSEN — DECISION ANALYSIS

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OBJECTIVE

- STANDARDIZED PROCEDURE
- GENERATE TRACEABLE PATHS
- INCORPORATE MULTI-FACETED DATA AND INFORMATION

DECISION ANALYSIS SOLUTION

- TREE STRUCTURE SUITED TO WIDE VARIETY OF PROBLEMS WITH MULTIPLE OBJECTIVES
- TREE ANALYSIS HIGHLIGHTS CRITICAL PATHS AND PARAMETERS OF PROBLEM
- TREE STRUCTURE HANDLES QUALITATIVE AND QUANTITATIVE DATA
  - UNCERTAINTY IS EASILY HANDLED BY SENSITIVITY ANALYSIS
  - EASILY UPDATED WITH NEW INFORMATION

360479-8 (6-27 83)

To verify decision analysis is a desirable methodology, a comparison is needed between the outlined objectives and the advantages of decision analysis. From the above chart, it is apparent decision analysis satisfies each of the outlined criteria and is therefore suited to the task outlined.

The remainder of this report addresses the specifics of applying the methodology to collection system problems. To do this a simple problem of information collection and evaluation will be used for illustrative purposes. By working a simple problem in detail, it is felt a more in-depth delineation of the methodology is obtained and problems which might be expected are highlighted and resolved.

The result of using this methodology is the introduction of structure and a standardized procedure to what has previously been an intuitive, unstructured analysis. The methodology will not replace or reduce the importance of expert opinion. The expert's opinion will, however, be more visible and available for review and discussion.

THREE PHASE APPROACH

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I. DETERMINATION OF TREE STRUCTURE AND THE ASSIGNMENT OF BRANCH WEIGHTS

II. DEFINITION OF COLLECTION CONCEPT AND THE DETERMINATION OF COLLECTION UNCERTAINTIES

III. APPLICATION OF OTHER FACTORS AND SENSITIVITY ANALYSIS

- TIMELINESS
- SURVIVABILITY

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The basic approach of the defined methodology divides into three phases. The first phase involves formulating the problem to be addressed in an information tree structure. This "tree" depicts the relationships and hierarchy of the problem from the top of the tree, the question to be answered, to the bottom of the tree, the collectable data items which combine to answer the overall issue. The intermediate stages of the tree form the linkages between collectable data and the overall question. Information at these levels might include system parameters, doctrine considerations, and deployment questions.

Once the structure has been outlined, weights are assigned to the branches to indicate a particular branch's importance in answering the overriding issue at the next highest level or node. A value between 0 and 1 is used to define this importance, 0 indicating no relevance (the branch could be eliminated from the tree) and 1 indicating this branch is the only relevant branch (all others emanating from this node could be eliminated).

With the tree structure complete and the weights assigned, the second phase begins with specification of the collection concepts along with their capabilities. Defining the concept involves establishing the probabilities the concept can collect the data described at the lowest levels of the tree. The probability assessment will in practice take the form of a distribution describing the likelihood of successful collection. By combining the concept definition with the tree structure, a result is obtained which delineates the value of information available to answer the overriding question of the tree.

Incorporation of outside factors not included in the tree structure or concept definition is accomplished in phase three. Considerations such as the availability or timeliness of a concept, or the availability of data from a given concept versus another, can be included in the analysis through the use of a discount factor. By allowing for the time value of information in this manner, concepts whose timing of availability differ can be compared. Additionally, concepts whose expected lifetimes differ can be analyzed in a similar manner. The additional information available because one system will have a longer lifetime than another can be handled by "compounding" the value obtained by the tree and concept definition analysis. The result achieved by completing phase three will be a probability distribution showing the information availability and its likelihood of collection. Using these distributions, alternative concepts can be evaluated keeping in mind risk aversion, minimum requirements or other factors.

III. ILLUSTRATIVE EXAMPLE OF METHODOLOGY

EXAMPLE PROBLEM

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JOHN IS CONSIDERING BUYING A HOUSE. HE HAS DRIVEN PAST ONE ON THE WAY TO WORK THAT LOOKS LIKE A GOOD POSSIBILITY

HE NOW HAS TO FIND INFORMATION ON HOW WELL THIS HOUSE FITS HIS NEEDS — BOTH OBJECTIVE AND SUBJECTIVE

HE WANTS TO KNOW

- WHAT IS THE BEST WAY TO COLLECT THE INFORMATION HE NEEDS TO MAKE A DECISION

STEP NO. 1: BUILD AN INFORMATION VALUE TREE

STEP NO. 2: ASSESS THE VALUE OF THE INFORMATION THAT CAN BE GATHERED BY COMPETING INFORMATION COLLECTION CONCEPTS

STEP NO. 3: EVALUATE OTHER FACTORS IMPACTING COLLECTION PERFORMANCE

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What follows is an in-depth discussion of the methodology which will describe why it can be such a powerful decision support tool and, more specifically,

- the techniques necessary to apply it,
- the information it can provide,
- the insight it will give to both analysts and decision makers.

As a supplement to this technical discussion, a simple example will be used to illustrate the key concepts of the methodology. Please note, however,

- the example is by necessity somewhat over-simplified in order to demonstrate the concepts; it is not intended to be completely realistic, and
- so that it can provide insight into how such an analysis is done, the example will be presented in a very detailed and numerically intensive manner.

The example centers around John who is considering buying a house. He has driven by one on the way to work that looks like a good possibility and now must collect information on how well this particular house fits his needs. Specifically he wants to know:

"What is the single most effective method to use to collect the information necessary to make this decision."

The basic steps John will need to follow to perform his analysis are:

(1) Build an information value tree to delineate the raw data that should be collected as well as the relative value of each piece to the main question.

(2) Assess collection concept performance by evaluating the ability of each candidate collection concept to meet each raw data requirement.

(3) Incorporate any other relevant factor and perform sensitivity analyses.

Note: This example has been specifically designed to illustrate all facets of the methodology and the reader should not be concerned that the techniques seem laborious and involved. In actual analyses many of the steps illustrated will not be necessary because sensitivities of the problem will allow some simplification.

III. A. INFORMATION TREE DEVELOPMENT

INFORMATION VALUE TREE

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REPRESENTS THE RELATIONSHIP BETWEEN DIFFERENT LEVELS OF INFORMATION NEED AND THE DATA ELEMENTS THAT SUPPORT THEM

DEVELOPED BY DRIVING DOWN ONE LEVEL OF INFORMATION AT A TIME FROM THE DECISION MAKER'S QUESTION TO THE AVAILABLE DATA

DEPICTED GRAPHICALLY BY

- NODES — REPRESENTING SOME QUANTUM OF INFORMATION
- BRANCHES — REPRESENTING EITHER
  - — THE TIE UP TO THE NEXT HIGHER LEVEL OF INFORMATION REQUIRING THIS PIECE OF INFORMATION
  - — THE TIES DOWN TO THE LOWER LEVELS OF INFORMATION ELEMENTS SUPPORTING THIS PIECE OF INFORMATION

ESTABLISHES THE RELATIVE VALUE BETWEEN ALL ELEMENTS OF INFORMATION RELATIVE TO EITHER

- A PARTICULAR NODE
- A PARTICULAR INFORMATION LEVEL

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An information value tree is a construct for relating different levels of information requirements and the raw data supporting them. It is a systematic structuring of how these information and data items relate. The information value tree is essentially a graph with

branches - which represent either data or pieces of information aggregated from lower levels of information or raw data, and

nodes - which represent the tieing together of the data or aggregated information to support a specific higher level information need, that is, a further aggregation of information.

The purpose of such a structure is to establish the value of each information need or data item relative to the particular information requirement (node) it supports as well as to any other information need or data item within the tree.

In structuring the information tree, the nodes employed can either be "or" or "and" in character. The node type selected will depend upon the structure and information required by the developer. Whichever structure type provides the greatest visibility to the developer should be employed. The only precaution needed for the actual analysis is the numerical combinations performed at each node must be consistent with the node type. For "and" nodes all branches into a node should be summed yielding the nodal result and for "or" nodes only the branches which are active, actually employed or satisfied, should be summed.

At the top of the next page is the tree John developed to evaluate which collection concept provides the most effective support relative to his main question: should he consider buying this house. This question is called the "decision maker question." From the tree it can be seen that for John, the utility or value of a house is solely a function of

- whether it fulfills certain critical needs he has established,
- the extent to which the house and yard will need to be cared for, and
- the investment required and the return expected.

These are the "critical issues" that drive the decision maker's question. In turn, each critical issue is defined by a set of "problem characteristics." For example, the investment potential has been broken down into the immediate affordability, the continuing affordability, and the future worth. The problem characteristics are themselves derived from "data items" which relate to pieces of information that are actually collected. Note that the complete set of data items that support the decision maker's question are on the far right side and range from the number of bedrooms in the house to the planned developments in the local area.

In general, the key concepts to consider at each level of the tree are as follows:

Decision Maker Question - the main question against which the collection concepts are being evaluated.

Critical Issues - the key issues or subquestions that drive the resolution of the decision maker question. These are still from a qualitative vs a quantitative perspective.

System/Problem Characteristics - quantifiable information that defines the key drivers behind the critical issues.

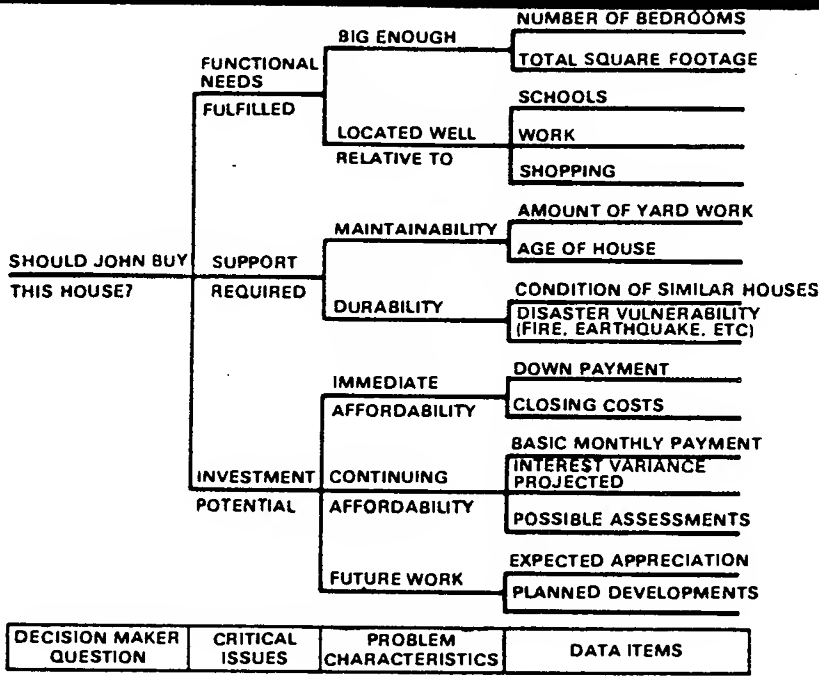
Data Items - data that is directly collected or directly derived from collected data.

These levels are guidelines to help the analyst in systematically constructing the tree structure such that all the relevant issues are addressed and the key data requirements are delineated. The structuring process can be done solely by the decision maker, as in this example, or in concert with a group of experts in the various areas spanned by the tree and is somewhat of an art. It is critical to be as systematic as possible; all the relevant information needs to be captured and, conversely, as little as possible of the extraneous. A key sign that some part of the tree's structure is essentially complete occurs when review of that section produces discussions revolving around semantics which generate no new insight or data .

The information represented at different levels of the tree ranges from very qualitative at the decision maker question level (e.g., should John consider buying this house) to very quantitative (e.g., the number of bedrooms in the house). Specifically, quantitative information can be described using numbers; examples might be the number available, dollars spent, percent lost, distance traveled, probability of occurrence. Qualitative information, on the other hand, is sometimes referred to as "intangible"; examples might be margin for safety, ability to predict, impact on the status quo, level of performance. One of the strengths of this decision analysis approach is the ability to tie together such different types of data.

JOHN'S TREE

HUGHES



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LEVELS OF THE TREE STRUCTURE

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I. DECISION MAKER QUESTION

- ULTIMATE QUESTION OR PROBLEM TO BE ADDRESSED BY REMAINDER OF THE TREE

II. CRITICAL ISSUES (KEY SUBQUESTIONS)

- QUALITATIVE QUESTIONS WHOSE SOLUTIONS ARE NECESSARY TO ANSWER DECISION MAKER QUESTION

III. SYSTEM/PROBLEM CHARACTERISTICS

- QUANTITATIVE SYSTEM PARAMETERS WHICH COMBINE TO PROVIDE AN ANSWER TO CRITICAL ISSUES

IV. RAW AND DERIVED DATA

- QUANTITATIVE DATA WHICH IS COLLECTED IN ITS RAW FORM BY COLLECTION SOURCE OR EASILY DERIVED FROM SUCH DATA

QUALITATIVE PERSPECTIVE

QUANTITATIVE PERSPECTIVE

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As John's tree is relatively simple, each level has only one set or tier of branches; this is not a requirement, however. More complex questions where more detail is necessary or even just desired may have several tiers of branches and nodes at each level. Additionally, the number of tiers or branches at a particular level does not have to be consistent throughout the tree. For example, instead of just stopping with a branch corresponding to the relative distance of the house to work, John could have put a node at the end of that branch and added two new branches that corresponded to the distance relative to where he works and relative to where his wife works. The more detailed the branch structure becomes, the more information it captures and the more insight it provides into the data and issues that drive the decision maker's question. Care must be taken, however, to avoid excessive detail; for example, the specific distance to every single school in the local area is not of any concern to John, so to break the tree down further in this area is undesirable.

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BRANCHING CRITERIA

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COMPLETENESS

- THE SET OF BRANCHES SHOULD CHARACTERIZE ALL THE SUPPORTING INFORMATION NECESSARY TO BE CONSIDERED AT A GIVEN NODE

SIGNIFIGANCE

- EACH BRANCH SHOULD REPRESENT AN IDENTIFIABLE AND MEASURABLE ELEMENT OF CONTRIBUTING INFORMATION

FAMILIARITY

- EACH BRANCH SHOULD BE UNDERSTANDABLE TO THE EXTENT IT IS POSSIBLE TO ESTABLISH A WEIGHTING RELATIVE TO THE OTHER BRANCHES AT THE SAME NODE

INDEPENDENCE

- TWO BRANCHES FROM THE SAME NODE SHOULD NOT
  - REPRESENT THE IDENTICALLY SAME INFORMATION REQUIREMENT
  - BE DEPENDENT ON EACH OTHER

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In developing an information value tree, there are some simple analytical guidelines for delineating the set of branches at a particular node. Since each node represents the tieing together of all its relevant data, the set of branches must be "complete", that is there must be a branch for each contributing piece of information. For example, "immediate affordability" is completely defined by what the down payment and the closing costs are. By the same reasoning, a branch should only be constructed if it represents a "significant" element of information, that is, it has some relevance to the information requirement represented by the node. The fact that the house has a tile roof is not relevant to whether it is big enough. Next, each branch should be "familiar", that is, it should represent a piece of information that both the analyst and reviewer can understand and evaluate. Last, all the branches should be "independent"; no two branches should depend directly on one another or represent the identically same piece of information.

III. B. DELINEATION OF INFORMATION TREE WEIGHTS

DELINEATION OF WEIGHTS

HUGHES

JOHN HAS NEVER BOUGHT A HOUSE BEFORE, SO HE IS NOT SURE WHAT THE RELATIVE IMPORTANCE OF THE VARIOUS ISSUES ARE

TO GAIN INSIGHT, HE CONSULTS SOME OF HIS FRIENDS (WHO HE BELIEVES TO BE KNOWLEDGEABLE IN THE AREA — LOCAL EXPERTS)

MARY: WHO IS IN THE PROCESS OF BUYING HER THIRD HOME

SUE: WHO HAS EXTENSIVE REAL ESTATE INVESTMENTS

GARY: WHO HAS NEVER BOUGHT A HOUSE, BUT WHO JUST FINISHED A SEMINAR FOR FIRST-TIME HOME BUYERS

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Once the structure of the information value tree has been established (the nodes and the branches have been defined), the next step is to delineate the relative value weightings. This can be done by the decision maker, in this case, John, or it can be delegated by the decision maker to a group of experts. Since John has virtually no experience in the real estate market, he decided he needed help in assigning the weights to the branches of his tree. So he selected three experts to advise him.

- Mary is in the process of buying her third home so she's had a fair amount of experience not only in actually buying a house, but also in maintaining one. Of all his "experts", she probably represents the one whose experience John feels is the most consistent with his perspective.
- Sue is very much involved in the real estate market and has many investments. She is predominately interested in investment potential.
- Gary has never bought a house but he just finished attending a seminar designed for first-time home buyers so he has information about what the "experts" say should be considered when buying a house.

The weight assigned to each branch reflects its value or contribution to the information requirement relative to the other branches emanating from the same node. This weight may range in value between 0 and 1 where

- 0 - the piece of information has no impact on the information requirement at all, and
- 1 - this piece of information is the only contributing information required.

The weights assigned to all the branches at a particular node must sum to 1, reflecting the premise that together they represent the complete set of significant information needed to define the information requirement at that node.

The actual calculation of the branch weights is a two step process. First, the relative value of all the branches at a particular node is established. For example, piece B of information may be twice as important as piece A and piece C of information may be three times as important as piece A. This can be analytically described by:

$$3*B = 6*A = 2*C$$

The next step is to normalize by forcing the weights to sum to 1 which gives:

$$A + B + C = A + 2*A + 3*A = 1$$

or

$$A = 1/6$$
$$B = 1/3$$
$$C = 1/2$$

By requiring the branch weights to sum to 1 at every node, a consistent value structure is forced on the entire tree, enabling the analyst to readily calculate the relative value of any piece of information or data item within the tree. Ultimately, this leads to a preference ranking over the set of collectables (data items) which can then be used to evaluate the set of potential collection concepts.

ASSIGNMENT OF RELATIVE VALUES

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PROCESS WHEREBY THE RELATIVE VALUE OF THE VARIOUS PIECES OF INFORMATION (BRANCHES) REQUIRED TO SUPPORT A PARTICULAR (HIGHER) LEVEL OF INFORMATION (NODE) ARE ESTABLISHED

VALUES (OR WEIGHTS) MAY RANGE BETWEEN 0 AND 1 WHERE

0 — HAS NO IMPACT AT ALL

1 — IS THE ONLY CONTRIBUTING FACTOR

AT A PARTICULAR NODE (QUANTUM OF INFORMATION), THE WEIGHTS ASSIGNED TO ALL THE CONNECTING BRANCHES (SUPPORTING INFORMATION) MUST SUM IDENTICALLY TO 1 TO ALLOW COMPARISON OF INFORMATION REQUIREMENTS AT NODES OF THE SAME AND HIGHER LEVELS

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CALCULATION OF BRANCH WEIGHTS

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GOALS:

- THE WEIGHTS REFLECT THE RELATIVE VALUE OF THE SUPPORTING INFORMATION TO DEFINING THIS PIECE OF INFORMATION
- ALL THE WEIGHTS CORRESPONDING TO THE SUPPORTING INFORMATION MUST SUM IDENTICALLY TO 1

PROCESS:

- ESTABLISH THE RELATIVE VALUE OF THE VARIOUS INFORMATION REQUIREMENTS, EG

  VALUE (B) = 2 • VALUE (A)
  VALUE (C) = 3•VALUE (A)

  OR

  3B = 6A = 2C

- NORMALIZE TO FORCE WEIGHT TO SUM TO 1, EG (AS, ABOVE)

  A + B + C = 1
  A + 2A + 3A = 1
  6A = 1
  A = 1/6, B = 1/3, C = 1/4

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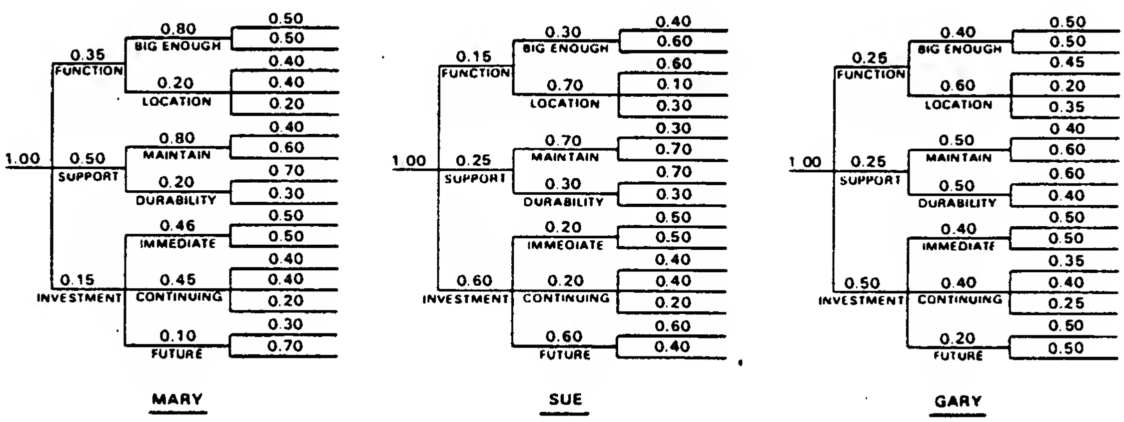
SAMPLE OF EXPERT OPINIONS

HUGHES



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Three very different sets of weights were provided by John's experts as shown in the trees above. Mary and Sue, for example, have divergent priorities for the "investment potential" in general and the "future worth" in particular. Mary is much more concerned about the supportability of the house and the functionality it provides; Sue, with her background in real estate investments, concentrates on the investment section of the tree. Gary has yet another set of weights although his are closer to Sue's.

The next issue for John is how to aggregate these three different perspectives into a single consensue tree.

The derivation of consensus weights for the decision maker's tree requires some procedure for aggregating the values for the weights provided by experts into a single set of estimates. Just summing the values up and taking the average, although a simple approach, does not take into account any information the decision maker may have about the differing levels of expertise the experts may have or any knowledge of their individual biases. Additionally, such a procedure provides no way to adjust the impact extreme opinions may have on the aggregation (either to emphasize or to mask them).

The question of how best to create a consensus position from a pool of expert opinions has received much attention from decision analysis experts. Many procedures have been proposed varying from the simplistic, such as the averaging approach suggested above, to the theoretically sophisticated; as yet, however, there is no general agreement about which approach yields the most valid results. However, to be useful for the collection systems problem, an aggregation procedure should meet four requirements:

(1) There should be a way to incorporate any preferences the decision maker may have between the experts so differing levels of emphasis can be assigned in proportion to the perception of their expertise.

(2) In order to preserve the relative value structure of the entire tree, the aggregation procedure must produce consensus weights such that the sum of the values assigned to the set of branches at any node is still exactly 1.

(3) The weight structure for any particular expert must be incorporated in such a way that his or her relative rankings are preserved.

(4) To enable the procedure to be as usable as possible, the information required to implement it should be readily available.

An example of one of the more analytic approaches that has been developed is a procedure proposed by Morris. It is a very rigorous Bayesian approach that uses each expert's past performance to condition, that is weight, his or her current prediction. Initially, the excellent theoretical foundation for this procedure, as well as others of a similar nature, seemed to strongly point to the implementation of such an approach within this methodology. Upon further investigation, however, the very strength of such procedures proved to also be their weakness, at least relative to the type of decision support methodology that is needed to handle the collection system problem. The application of approaches such as Morris's requires access to a reasonably large sized data base describing the performance of the expert with similar problems. Typically, such a data base is not available. As a result, the approach selected for implementation with this methodology is less sophisticated but in return the decision maker will have more control of how the consensus is to be achieved. If over time the data base necessary to support a method such as Morris' can be accumulated, a more sophisticated approach can be added to the procedure suggested in this report.

AGGREGATION OF EXPERT OPINION

HUGHES

COMBINING THE OPINIONS OF SEVERAL EXPERTS IN A VALID MANNER ONE NEEDS TO CONSIDER

- DIFFERING LEVELS OF EXPERTISE BETWEEN EXPERTS
- INDIVIDUAL BIASES
- EFFECTS OF EXTREME OPINIONS

METHODOLOGY CHOSEN MUST ALLOW FOR THE ADJUSTMENTS NECESSARY AND ALSO BE SATISFACTORY IN THE

- TEMPORAL
- REASONABLE IN THE AMOUNT OF DATA REQUIRED
- EASILY TRANSFERABLE AND AT THE SAME TIME MAINTAIN AS MUCH DATA AS POSSIBLE

350479-48 (6-27 83)

MORRIS APPROACH

HUGHES

- APPROACH TO EXPERT RESOLUTION OR CONSENSUS DISCUSSED IN THE PROPOSAL
- RIGOROUS BAYESIAN APPROACH
- BASED ON PRIOR PERFOMANCE OF EXPERTS
- DRAWBACK
  - DATABASE ON PRIOR PERFORMANCE NOT TYPICALLY AVAILABLE
- APPROACH SELECTED
  - LESS TECHNICAL
  - GIVES THE DECISION MAKER MORE DIRECT CONTROL OF THE CONSENSUS PROCESS

360479-68 (6 27 83)

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For the collection systems problem, the approach selected to derive the consensus estimate from a set of expert opinions is based on a weighted average of the experts' opinions. Given the estimates of N experts for a value to be assigned to a particular weight,

V(1), V(2), ..., V(N),

as well as a set of preferences (or weights) from the decision maker associated with each of these experts,

W(1), W(2), ..., W(N),

the consensus value (W*) is the normalized weighted average of the experts' opinions, that is, the weighted average divided by the sum of the weights,

$$W^* = \frac{1}{\sum_{i=1}^{N} W_i} * [\sum_{j=1}^{N} W_j * V_j].$$

This approach, besides being very straightforward to apply, is appealing in the way it allows the decision maker to emphasize the estimates of the various experts in a way that is consistent with his or her evaluation of each of the experts. Another benefit is that it does not require the extensive historical database needed to implement an approach like Morris's. In fact, if the decision maker has no preference between the experts, the weights, W_i, can be set identically to 1.

John has decided that of his three experts, Mary's perspective is the one that most closely matches his position. As such, he feels that her estimates should be weighted about twice as much as either Sue's or Gary's, whose opinions he feels should be weighted about equally. The resulting preferences or weights are

Mary:	2
Sue:	1
Gary:	1

Using these values, John calculates the consensus weights for his information value tree. As an example, the expert opinions associated with the branch for "functional needs" are

Mary:	0.35
Sue:	0.15
Gary:	0.25

giving a consensus weight of

$$W^* = (1/4)*[(2)(0.35) + (1)(0.15) + (1)(0.25)]$$
$$= 0.275$$

The complete set of consensus estimates for the weights are shown in the adjoining table.

CONSENSUS METHODOLOGY

HUGHES

GIVEN

- A SET OF WEIGHTS OR RELATIVE VALUES PROVIDED BY N EXPERTS,

$$V_1, \ldots, V_N$$

- A SET OF DECISION MAKER PREFERENCES OR WEIGHTS ASSOCIATED WITH THOSE N EXPERTS,

$$W_1, \ldots, W_N$$

THEN

- THE CONSENSUS WEIGHT, W*, IS DEFINED BY

$$W^* = \frac{1}{\sum_{i=1}^{N} W_i} \sum_{j=1}^{N} W_j V_j$$

EXAMPLE

- IF $V_1 = 0.35, V_2 = 0.15, V_3 = 0.25$
  $W_1 = 2, W_2 = 1, W_3 = 1$
- THEN $W^* = \frac{1}{4}$ (2) (0.35) + (1)(0.15) + (1) (0.25) = 0.275

360479-29 (6-27-83)

HUGHES

CALCULATION OF CONSENSUS WEIGHTS

	MARY	SUE	GARY	CONSENSUS	RELATIVE TO TREE
EXPERT PREFERENCES/WEIGHTS	2	1	1	–	–
FUNCTIONAL NEEDS	0.35	0.15	0.25	0.275	0.275
BIG ENOUGH	0.80	0.30	0.40	0.575	0.158
BEDROOMS	0.50	0.40	0.50	0.475	0.075
SQ FOOTAGE	0.50	0.60	0.50	0.525	0.083
LOCATION	0.20	0.70	0.60	0.425	0.117
SCHOOLS	0.40	0.60	0.45	0.463	0.054
WORK	0.40	0.10	0.20	0.275	0.032
SHOPPING	0.20	0.30	0.35	0.262	0.031
SUPPORT REQUIRED	0.50	0.25	0.25	0.375	0.375
MAINTAINABILITY	0.80	0.70	0.50	0.700	0.262
AMT OF YARD WORK	0.40	0.30	0.40	0.375	0.098
AGE OF HOUSE	0.60	0.70	0.60	0.625	0.164
DURABILITY	0.20	0.30	0.50	0.300	0.113
CONDITION OF SIMILAR	0.70	0.70	0.60	0.675	0.076
DISASTER VULNERABILITY	0.30	0.30	0.40	0.325	0.037
INVESTMENT POTENTIAL	0.15	0.60	0.50	0.350	0.350
IMMEDIATE AFFORDABILITY	0.45	0.20	0.40	0.375	0.131
DOWN PAYMENT	0.50	0.50	0.50	0.500	0.065
CLOSING COSTS	0.50	0.50	0.50	0.500	0.066
CONTINUING AFFORDABILITY	0.45	0.20	0.40	0.375	0.131
BASIC MONTHLY	0.40	0.40	0.35	0.388	0.051
INTEREST	0.40	0.40	0.40	0.400	0.052
PROJ. ASSESSMENTS	0.20	0.20	0.26	0.212	0.028
FUTURE WORTH	0.10	0.60	0.20	0.250	0.088
EXP. APPRECIATION	0.30	0.60	0.50	0.425	0.037
PLANNED DEVELOPMENT	0.70	0.40	0.50	0.575	0.051

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The consensus tree developed by John is shown on the adjoining page at the left in the top figure. As required, the weights associated with the branches at each node sum to 1. John has reviewed this tree and is fairly comfortable with both the structure and the weights.

On the right of the figure is another version of the same consensus tree which shows the relative value of each piece of information to all other items at the same level instead of just those items at the same node. The "maintainability" issue, for example, is evaluated to be three times as important as the question of the house's "future worth". For this version of the tree, the values are calculated by multiplying the series of branch weights from the original tree along the tree from the decision maker question to that specific branch. In the case of the "maintainability" branch, the weight is calculated by multiplying the weight for that branch times the weight for the "support" branch, that is,

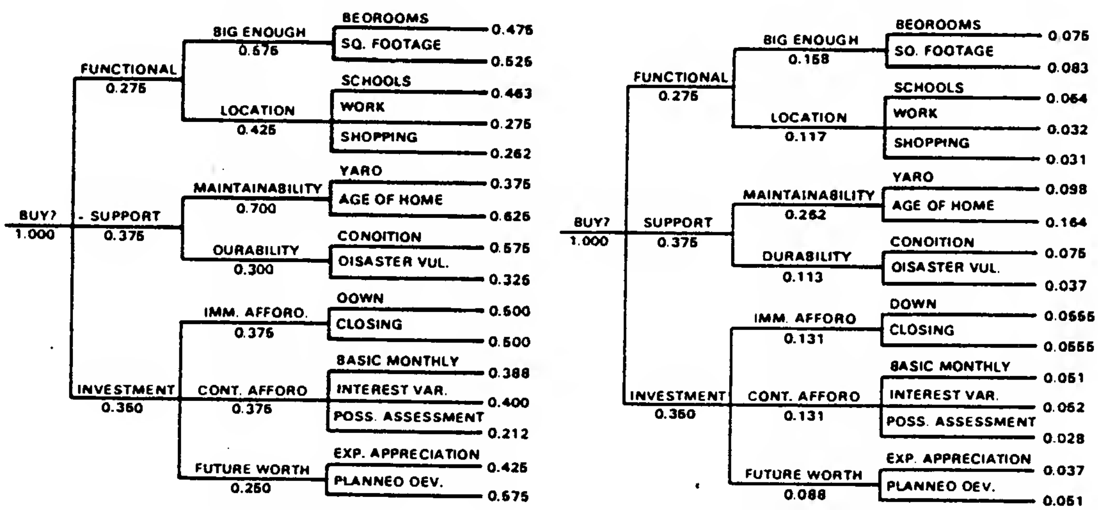
$$W = (0.700)*(0.376)$$
$$= 0.2622$$

This approach to structuring the information value tree provides a ranking at each level of all the corresponding information requirements. This is particularly useful at the data item level as it produces a prioritization of the collection requirements. In John's tree, the most important data item to be collected, the branch with the high relative value is the "age of the house" (0.164); at the other end of the spectrum, the least important data item is "possible assessments" (0.028). This modified form of the tree makes it readily apparent that the chief issue seems to be the support of the house and, more specifically, the maintenance of the house, whereas the least concern is given to its future worth.

This completes the first step of the analysis, the development of an information value tree. The decision maker now has insight into the data items that would be desirable to collect as well as their relative importance. This ranking will be useful in the next step, the evaluation of the various candidate collection concepts.

JOHN'S CONSENSUS TREE

HUGHES



BRANCH VALUES RELATIVE TO NODES

BRANCH VALUES RELATIVE TO EACH LEVEL

360479-31 (6-27-83)

PRELIMINARY CONCLUSIONS

HUGHES

- CHIEF ISSUE
  - MAINTAINABILITY OF THE HOUSE, SPECIFICALLY AS IT PERTAINS TO ITS AGE
- MOST IMPORTANT DATA ITEM
  - AGE OF HOUSE
- LEAST IMPORTANT DATA ITEMS
  - POSSIBLE ASSESSMENTS
  - LOCATION RELATIVE TO SHOPPING
  - LOCATION RELATIVE TO WORK
  - EXPECTED APPRECIATION
  - DISASTER VULNERABILITY

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INFORMATION COLLECTION CONCEPTS

HUGHES

NEXT STEP: ASSESS THE PERFORMANCE (I.E., THE VALUE OF THE INFORMATION COLLECTED) OF THE VARIOUS INFORMATION COLLECTION CONCEPTS TO BE STUDIED

ACCOMPLISHED BY ASCERTAINING EACH CONCEPT'S ABILITY TO COLLECT EACH REQUIRED DATA ITEM IN TERMS OF

- EXPECTED LIKELIHOOD OF COLLECTING THE REQUIRED DATA
- THE MINIMUM LIKELIHOOD OF COLLECTION
- THE MAXIMUM LIKELIHOOD OF COLLECTION

WHERE THE LIKELIHOOD OF COLLECTION IS A FUNCTION OF

- THE PROBABILITY OF COLLECTING THE DATA
- THE QUALITY OF THE DATA COLLECTED, I.E., THE ABILITY TO SUPPORT THE SUCCEEDING INFORMATION REQUIREMENTS

360479-33 (6-27-83)

The next step of the methodology focuses on the evaluation of the ability of each candidate concept to meet each raw data collection requirements. This, combined with the relative weight structure derived in the previous step, will provide a means for analyzing collection performance.

For each concept, the collection ability relative to each data requirement will need to be specified not only in terms of its expected or likely performance, but in order to be able to do confidence assessments, minimum and maximum performance levels will also need to be delineated. All performance likelihoods are a combination of both the probability of collection and the quality of what is collected relative to the data requirement. For example, relative to information about "planned developments" in the local area, if one of John's candidate concepts on the average will have an 80% chance of collecting some data, and if collected, the data will probably cover 95% of the developments, then a likely performance level, P, would be

$$P = .80 * .95$$

or approximately 75%. Quality thresholds, i.e., stipulation that if the data is not at least a certain quality it is not any good at all, are handled by assigning a 0 to the quality factor if it falls below the threshold.

John has identified four candidate approaches to collect the data he needs:

(1) Drop by the house in question and talk with the owner.
(2) Call up the city for information.
(3) Arrange with a friend (who is a real estate agent) to get the necessary data.
(4) Check the newspaper to see if the owner is advertising the house.

There may be other approaches that he might use, but these four are the ones under consideration. The question then is which one is the most effective collection concept, which one will collect the information with the highest overall potential value.

The first step in evaluating any of these collection concepts is to define the concept's ability to collect each data item in terms of its best or maximum performance, its worst or minimum performance, and its likely or expected performance. Data on the performance of the concepts can be provided by the decision maker or by an expert or experts designated by the decision maker. In the case of more than one expert, the same consensus techniques used to delineate the branch weights can be applied.

The table on the adjoining page summarizes the performance data for John's problem for each of his collection concepts, For example, in the area of "disaster vulnerability", John's estimate is that the owner's likelihood of supplying him that information is somewhere between 40% and 60%, the city's likelihood is between 60% and 80%, and his friend's likelihood is between 50% and 70%. He does not expect to find this particular data item in a newspaper advertisement.

POTENTIAL SOURCES FOR JOHN'S DATA

HUGHES

JOHN HAS IDENTIFIED 4 POTENTIAL WAYS TO COLLECT THE DATA HE NEEDS:

(1) DROP BY THE HOUSE IN QUESTION AND TALK WITH THE OWNER

(2) CALL UP THE CITY FOR INFORMATION

(3) ARRANGE WITH A FRIEND WHO IS A REAL ESTATE AGENT TO GET THE NECESSARY DATA

(4) CHECK THE NEWSPAPER TO SEE IF THE OWNER IS ADVERTISING THIS HOUSE

HE NOW NEEDS TO DEFINE THE PERFORMANCE OF EACH OF THESE RELATIVE TO EACH DATA REQUIREMENT IN TERMS OF MINIMUM, EXPECTED, AND MAXIMUM PERFORMANCE

- CAN BE DONE BY THE DECISION MAKER OR BY USING EXPERT CONSULTATIONS AND CONSENSUS TECHNIQUES AS WAS DONE WITH THE WEIGHTS

380479-33 (6-27-83)

INFORMATION PERFORMANCE FACTORS

HUGHES

	TALK WITH OWNER			TALK WITH CITY			TALK WITH FRIEND (AGENT)			CHECK NEWSPAPER		
	MIN	EXP	MAX	MIN	EXP	MAX	MIN	EXP	MAX	MIN	EXP	MAX
NUMBER OF BEDROOMS	1.0	1.0	1.0	0	0	0	0.8	0.9	1.0	0	0	0
SQUARE FOOTAGE	1.0	1.0	1.0	0	0	0	0.6	0.8	1.0	0.5	0.7	0.9
SCHOOLS (LOCATION)	0.5	0.7	0.9	0.8	0.9	1.0	0.5	0.7	0.9	0.2	0.3	0.4
WORK (LOCATION)	0.1	0.2	0.3	0	0	0	0.2	0.5	0.8	0	0	0
SHOPPING (LOCATION)	0.2	0.45	0.7	0.2	0.3	0.4	0.4	0.65	0.9	0.1	0.2	0.3
AMOUNT OF YARD WORK	0.7	0.85	1.0	0	0	0	0	0	0	0	0	0
AGE OF HOME	0.9	0.95	1.0	0.3	0.5	0.7	0.4	0.6	0.8	0.2	0.35	0.5
CONDITION OF SIMILAR HOMES	0.5	0.7	0.9	0	0	0	0.3	0.5	0.7	0	0	0
DISASTER VULNERABILITY	0.4	0.5	0.6	0.6	0.7	0.8	0.5	0.6	0.7	0	0	0
DOWN PAYMENT	0	0	0	0	0	0	0.7	0.8	0.9	0	0	0
CLOSING COSTS	0	0	0	0	0	0	0.4	0.6	0.8	0	0	0
BASIC MONTHLY PAYMENT	0	0	0	0	0	0	0.7	0.8	0.9	0	0	0
PROJECTED INTEREST VARIANCE	0	0	0	0	0	0	0.4	0.55	0.7	0	0	0
POSSIBLE ASSESSMENTS	0.2	0.4	0.6	0.4	0.55	0.7	0.3	0.5	0.7	0.1	0.15	0.2
EXPECTED APPRECIATION	0.2	0.3	0.4	0.1	0.2	0.3	0.5	0.65	0.8	0	0	0
PLANNED DEVELOPMENTS	0.4	0.55	0.7	0.7	0.8	0.9	0.6	0.75	0.9	0.1	0.15	0.2

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Once the information has been gathered on the performance range of each candidate collection concept, the next step is to evaluate their expected performance. For each information requirement, this is expressed in terms of an expected information value which is determined by multiplying the expected performance level by the corresponding relative weight from the modified information value tree. In the case of the third collection concept (talking with his friend) and the first collection requirement (the number of bedrooms),

relative value of information = 0.075
expected performance = 0.9
expected information value = (0.9)*(0.075)
= 0.0676

The expected information values are in turn summed over the entire tree to provide the overall expected information value for the complete tree for each concept. These can be compared to determine the collection concept with the highest expected performance.

The adjoining table contains the expected performance figures for each of the collection concepts in John's problem. The first and the third concepts (talking with the owner and talking with his friend) have markedly higher expected performance than the remaining candidates. The margin between the top two, however, is close enough that it is difficult at this point to differentiate between them; not enough is known, only the expected performance has been compared, not the complete performance range. To do this, John will need to move into the third phase of the evaluation provess, the sensitivity analysis.

PERFORMANCE ANALYSIS

HUGHES

THE INITIAL CONCEPT ANALYSIS IS BASED ON THE EXPECTED PERFORMANCE OF EACH CANDIDATE COLLECTION CONCEPT AND USES

- EXPECTED PERFORMANCE LIKELIHOODS
- CONSENSUS WEIGHTS

BASICALLY INVOLVES WEIGHTING THE EXPECTED PERFORMANCE LIKELIHOODS WITH THE WEIGHTS (RELATIVE TO THE DATA ITEM LEVEL) ASSOCIATED WITH THE INFORMATION REQUIREMENTS

EXPECTED PERFORMANCE

HUGHES

INFORMATION SOURCE	EXP. VALUE
TALK WITH THE OWNER	0.58
TALK WITH THE CITY	0.23
TALK WITH FRIEND (AGENT)	0.60
CHECK NEWSPAPER	0.15

(Reverse Blank)

SENSITIVITY ANALYSIS

HUGHES

- SENSITIVITY ANALYSIS IS THE CRUCIAL STEP OF THE METHODOLOGY
  - PROVIDES DECISION MAKER WITH THE QUANTITATIVE LIMITS OVER WHICH HIS/HER QUALITATIVE DECISION WILL BE VALID
- ANALYSIS CAN BE APPLIED SEVERAL PLACES
  - OVERALL TREE
  - INTRALEVEL ON THE TREE
  - BETWEEN CONCEPTS
  - INTERNAL TO CONCEPT ANALYSIS
- METHODS
  - WORST CASE/BEST CASE
  - MONTE CARLO

The sensitivity analysis is perhaps the most critical phase in the methodology because it provides the decision maker insight into the limits over which the collection concept selected is the most effective. Finding the concept with the highest expected value for the information collected is only the first part of the solution; it is equally important to understand the range over which it is the most effective solution and how sensitive the value of the information collected is to variances in each concept's performance relative to the various information requirements.

Classically, sensitivity analysis refers to procedures in which parameters are varied over their possible values in order to determine the degree of variation in the resulting solution. Here sensitivity analysis will be used in two ways

- to evaluate the impact on the overall information value over the entire range (not, just the expected value) of each collection concept's performance relative to the various information requirements, and
- to incorporate factors in addition to the value of information that differentiate the performance of various collection concepts.

Note: The reader is once again warned that the example illustrated here has been specifically designed to illustrate all aspects of the developed methodology. In actual practice, not all the steps shown will be necessary as each problem will possess possibilities for simplification.

JOHN'S PERFORMANCE ANALYSIS

HUGHES

	TALK WITH OWNER		TALK WITH CITY		TALK WITH FRIEND (AGENT)		CHECK NEWSPAPER	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
NUMBER OF BEDROOMS	0.58	0.58	0.23	0.23	0.60	0.61	0.15	0.15
SQUARE FOOTAGE	0.58	0.58	0.23	0.23	0.59	0.62	0.13	0.17
SCHOOLS (LOCATION)	0.57	0.59	0.23	0.23	0.59	0.61	0.14	0.16
WORK (LOCATION)	0.58	0.58	0.23	0.23	0.59	0.61	0.15	0.15
SHOPPING (LOCATION)	0.57	0.59	0.23	0.23	0.60	0.61	0.15	0.15
AMOUNT OF YARD WORK	0.56	0.59	0.23	0.23	0.60	0.60	0.15	0.15
AGE OF HOME	0.57	0.59	0.20	0.26	0.57	0.64	0.12	0.18
CONDITION OF SIMILAR HOMES	0.56	0.59	0.23	0.23	0.59	0.62	0.15	0.15
DISASTER VULNERABILITY	0.58	0.58	0.23	0.23	0.60	0.61	0.15	0.15
DOWN PAYMENT	0.58	0.58	0.23	0.23	0.60	0.61	0.15	0.15
CLOSING COSTS	0.58	0.58	0.23	0.23	0.59	0.62	0.15	0.15
BASIC MONTHLY PAYMENT	0.58	0.58	0.23	0.23	0.60	0.61	0.15	0.15
PROJECTED INTEREST VARIANCE	0.58	0.58	0.23	0.23	0.60	0.61	0.15	0.15
POSSIBLE ASSESSMENTS	0.58	0.58	0.23	0.23	0.60	0.61	0.15	0.15
EXPECTED APPRECIATION	0.58	0.58	0.23	0.23	0.60	0.61	0.15	0.15
PLANNED DEVELOPMENTS	0.57	0.59	0.23	0.23	0.60	0.61	0.15	0.15

360479-36 (8-27-83)

The first step of a more in-depth analysis of the performance of the various candidate collection concepts involves investigating the changes in the overall value of the information collected at the limits of the performance ranges associated with the various information requirements. The purpose of such an analysis is to determine

- the impact each collection requirement has over its performance range on the value of information collected, and
- the degree to which the various concepts overlap, that is, are indistinguishable.

The effect of the performance of each concept relative to each information requirement is studied by re-calculating the overall value of the information collected by

- fixing the performance of the requirement under consideration first at its minimum and then its maximum performance level, and
- using the expected value performance estimates for all other information requirements.

This provides the analyst insight into the factors that determine which concepts are the most effective.

The results of such a performance analysis are summarized in the adjoining table. Each entry represents the impact relative to a particular collection concept of evaluating a specific information requirement at either the minimum or maximum (versus expected) level of concept performance. There are a couple of observations of note.

- The impact of some of the information requirements seems to be independent of whether collection concept performance is fixed at its minimum, expected, or maximum level of performance. Examples are:
    - number of bedrooms
    - location relative to work
    - disaster vulnerability
    - down payment
    - basic monthly payment
    - projected interest variance
    - possible assessments
    - expected appreciation

  When this occurs, a more detailed analysis to determine the exact way in which collection concept performance varies between its minimum and its maximum levels is unnecessary; it's adequate to fix its performance at the expected level.
- The four candidate concepts have different ranges of information value:

(1) Talking with owner	56-59%
(2) Talking with the city	20-26%
(3) Talking with friend	57-63%
(4) Checking newspaper	12-18%

  The range of values for concept #2 and for concept #4 in no way overlaps that of any of the other concepts. However, concept #1 and #3 overlap considerably. Usually talking with the friend seems to have a higher return than talking with the owner, but not always (see "age of house" for example).

INCORPORATION OF OTHER FACTORS

HUGHES

THE EVALUATION OF COLLECTION CONCEPT PERFORMANCE MUST INCLUDE TWO OTHER FACTORS
- TIMELINESS
- SURVIVABILITY

TIMELINESS
- THE IMPACT ON THE VALUE OF THE INFORMATION COLLECTED DUE TO THE DELAYS IN IMPLEMENTING THE CONCEPT OR DELAYS IN THE CONCEPT OF PRODUCING THE DATA

SURVIVABILITY
- THE IMPACT ON THE VALUE OF THE INFORMATION COLLECTED DUE TO THE LIKELIHOOD OF THE COLLECTION CONCEPT ENDURING OR SURVIVING

BOTH ARE FUNCTIONS OF EITHER
- THE DECISION MAKER'S PERCEPTIONS, OR
- THE CONSENSUS RESULT OF GATHERING THE OPINIONS OF EXPERTS SELECTED BY THE DECISION MAKER

The evaluation of collection concept performance must include two other factors: timeliness and survivability. While the overall value of the information collected is the key discriminant between concepts, that value can be impacted by delays in implementing it or by the length of time over which it continues to provide information. The extent of that value impact is a function of the performance of the concept as well as the decision maker's evaluation of its importance.

A key concern in collection system analyses is the incorporation of revisit times or capabilities into the analyses. Revisit capabilities are accounted for in one of two ways in the methodology. The first approach, which is the most straightforward and easily applied, involves incorporating revisits into the collection concept performance assessment. With this approach the concept is viewed over time with the assessment of capability including several collection time intervals or opportunities. In simple terms, the question to be answered would be: Given the concept will visit this often and have these attempts at collection, what is the probability you will satisfy this particular information need? In this sense the concept capability includes performance over time and the details of individual visits or opportunities are suppressed in favor of an overall performance assessment.

The second alternative which can be applied to revisit questions involves using discounting methods similar to those discussed under concept survivability. In this approach each opportunity is analyzed individually and multiple opportunities over time are combined using the discounting methods discussed later in this section (see page 46). The application of this method involves selecting an appropriate discount factor.

The selection of either the overall performance assessment or the discounted assessment will depend upon analyst confidence and knowledge. The ultimate goal, however, is an assessment of overall performance which the analyst feels is believable and accurately reflects systems capabilities.

TIMELINESS

HUGHES

- GIVEN
  V=VALUE OF INFORMATION NOW
  N=AMOUNT OF TIME BEFORE IT CAN BE COLLECTED
  Ft(N)=DISCOUNT FACTOR TO BE APPLIED TO INFORMATION VALUE GIVEN A DELAY OF N
  Pt(N)=PROBABILITY OF A DELAY OF N
- THEN
  Et (V)=EXPECTED VALUE OF INFORMATION GIVEN TIMELINESS CONSIDERATIONS

$$=V\sum_j Ft(j) * Pt(j)$$

350479 65 10 27 831

When there is a gap between the point in time the need for some information is assessed and when it is actually received, the value of what is collected may be reduced. To evaluate collection concepts with different delays, the decision maker must specify to what extent delays of various durations impact the overall value of the information collected. This impact is expressed as a discounting factor on the overall value of information.

Given

V	=	overall value of information relative to some decision maker question
N	=	number of intervals that the collection of that information is delayed
$F_t(N)$	=	timeliness discount factor associated with a delay of N intervals

then

$V_t(N)$	=	discounted value of information given a delay of N intervals
	=	$V*F_t(N)$

Typically, the discount factors, $F_t(N)$, are expressed as elements in a discount stream, i.e., if each period of delay corresponds to "p" percent loss, then

$$F_t(N) = \left[\frac{1}{1+p}\right]^N$$

For example, a 5% discount factor for 4 periods would be

$$F_t(4) = \left[\frac{1}{1+.05}\right]^4$$

$$= 0.8227$$

Since the decision maker may not be able to predict a priori the exact number of intervals that the receipt of information may delayed, there is usually a need to specify the probability of delays of various duration and to evaluate the expected discounted value of information.

Given

$P_t(N)$ = probability of a delay of N intervals

then

$E_t(N)$ = expected value of information discounted for timeliness

$$= \sum_{j=1}^{M} [V_t(j) * P_t(j)]$$

$$= V* \sum_{j=1}^{M} [F_t(j) * P_t(j)]$$

Note that the probability distribution does not need to be specified in a detailed way. It is sufficient to grossly estimate it over a handfull of points; for example,

$P_t(0) = 0.2$
$P_t(1) = 0.4$
$P_t(2) = 0.3$
$P_t(3) = 0.1$

SURVIVABILITY

HUGHES

- GIVEN
  V=VALUE OF INFORMATION NOW
  N=AMOUNT OF TIME OVER WHICH IT WILL BE COLLECTED
  Fs(N)=ENHANCEMENT FACTOR TO BE APPLIED FOR INFORMATION IN THE Nth PERIOD
  Ps(N)=PROBABILITY OF AN ADDITIONAL N PERIODS
- THEN
  Es(V)=EXPECTED VALUE OF INFORMATION GIVEN SURVIVABILITY CONSIDERATIONS

$$= V * \sum_{k} P_s(k) * [\sum_{j=0}^{k} F_s(j)]$$

When information is collected over an extended period of time, the value of what is collected may be enhanced. To evaluate collection concepts with different survivabilities, the decision maker must specify to what degree extended collection enhances the overall value of the information collected. This impact is expressed as a compounding of value over the number of intervals.

Given

V = overall value of information relative to some decision maker question

N = number of intervals over which the collection of that information continues

$F_s(N)$ = relative value of some information in the Nth interval

then

$V_s(N)$ = enhance value of information over N intervals

$$= \sum_{j=0}^{N} V*F_s(j)$$

In other words, the decision maker must specify the incremental benefit of each additional interval of collection. If there is none, then $F_s(j)$ is set

to zero. As with timeliness, however, these compounding factors are typically expressed as elements in a discount stream, i.e., if each interval of extended collection corresponds to a "p" percent discount factor, then

$$F_s(N) = \left[\frac{1}{1+p}\right]^N$$

Since the decision maker may not be able to predict a priori the exact number of intervals over which the receipt of information may continue, the probability of survival over various durations usually must be specified and the expected enhanced value of information evaluated.

Given

$P_s(N)$ = probability of surviving N intervals

then

$E_s(N)$ = expected value of information enhanced for survivability

$$= \sum_{k=0}^{N} \left\{ V_s(k) * P_s(k) \right\}$$

$$= V * \sum_{k=0}^{N} \left\{ P_s(k) * \sum_{j=0}^{k} [F_s(j)] \right\}$$

Again, the probability distribution does not need to be specified in a detailed way. It is sufficient to grossly estimate it over a handful of points. For example,

if additional information is discounted at a rate of 10%, and

$P_s(0) = 0.4$
$P_s(1) = 0.3$
$P_s(2) = 0.2$
$P_s(3) = 0.1$

then over 3 years

$$E_s(3) = V * \sum_{k=0}^{3} \left\{ P_s(k) * \sum_{j=0}^{k} \left[\left(\frac{1}{1+.1}\right)^k\right] \right\}$$

$$= V * \left\{ (.4*1) + .3 * \left(1+\frac{1}{1.1}\right) + .2 * \left(1+\frac{1}{1.1} + \frac{1}{(1.1)^2}\right) + .1 * 1 + \frac{1}{1.1} + \frac{1}{(1.1)^2} + \frac{1}{(1.1)^3} \right\}$$

$$= 1.8685 * V$$

ADJUSTMENTS TO JOHN'S ANALYSIS

HUGHES

IN ORDER TO GET THE INFORMATION FROM HIS REAL ESTATE FRIEND, JOHN WILL HAVE TO WAIT AT LEAST TWO WEEKS UNTIL HE COMES BACK FROM VACATION

JOHN FEELS THAT THIS INEFFICIENT USE OF TIME WILL REDUCE THE VALUE OF THE INFORMATION HE COLLECTED BY THE FACTORS

$$\frac{1}{1.050} \approx .95$$

ALL OTHER CONCEPTS HAVE COMPARABLE

- TIMELINESS
- SURVIVABILITY

THEREFORE THE PERFORMANCE ANALYSIS NEEDS TO BE RECONSIDERED

350479-60 (6-27-83)

In order to get the information from his friend in real estate, John will have to wait at least two weeks until he comes back from vacation. Over this period of time, John feels that the value of the information that will be collected will degrade somewhat due to the fact that the house may go off the market. Therefore he estimates that a delay of two weeks will discount the value of what is collected by about 5%, for a discount factor, F, of

$$F = 1/1.05 \approx 0.95$$

This third collection concept is the only one expected to have such a delay; John expects to be able to implement any of the others immediately.

To adjust John's analysis to reflect this delay in timeliness for the third candidate collection concept, what is required is the reduction of all the relative values associated with the information requirements by 0.95 since by the time the information is collected it will have been discounted in value

by about 5%. For example, the expected information value the third collection concept is expected to collect for the first collection requirement, the number of bedrooms, is recalculated by

relative value of information = (1/1.05) * (0.075) ≈ 0.072
expected performance = 0.9
expected information value = (0.9) * (0.072) ≈ 0.0648

When all of the expected information values have been recalculated, they are again summed to determine the discounted expected value for the information collected.

The adjoining tables show the effect that the discounting had on both the performance factors associated with the third concept and on the performance analysis as a whole. The expected performance of the third concept, talking with the friend who is a real estate agent, typically is reduced between 3 and 4 percent across all of the information requirements. As for the comparison of the complete set of collection concepts, a check of the performance ranges shows that while concepts 2 and 4 are still much lower than 1 and 3, the choice between 1 and 3 is even less clear than before.

ADJUSTED PERFORMANCE FACTORS

HUGHES

	ORIGINAL		DISCOUNTED	
	MIN.	MAX.	MIN.	MAX.
NUMBER OF BEDROOMS	.60	.61	.57	.57
SQUARE FOOTAGE	.59	.62	.56	.59
SCHOOLS (LOCATION)	.59	.61	.56	.59
WORK (LOCATION)	.59	.61	.57	.58
SHOPPING (LOCATION)	.60	.61	.57	.58
AMOUNT OF YARD WORK	.60	.60	.57	.57
AGE OF HOME	.57	.64	.54	.61
CONDITION OF SIMILAR HOMES	.59	.62	.56	.59
DISASTER VULNERABILITY	.60	.61	.57	.57
DOWN PAYMENT	.60	.61	.57	.57
CLOSING COSTS	.59	.62	.56	.59
BASIC MONTHLY PAYMENT	.60	.61	.57	.57
PROJECTED INTEREST VARIANCE	.60	.61	.57	.57
POSSIBLE ASSESSMENTS	.60	.61	.57	.57
EXPECTED APPRECIATION	.60	.61	.57	.57
PLANNED DEVELOPMENTS	.60	.61	.57	.58

350479-53 (6-27-83)

PERFORMANCE RANGES

HUGHES

INFORMATION SOURCE	MIN. VALUE	MAX VALUE
TALK WITH OWNER	.56	.59
TALK WITH CITY	.20	.26
TALK WITH FRIEND (AGENT)	.54	.61
CHECK NEWSPAPER	.12	.18

350479-61 (6-27-83)

STOCHASTIC DOMINANCE

HUGHES

- A CONCEPT IS COMPLETELY DOMINATED IF THERE IS AT LEAST ONE OTHER CONCEPT HAVING ALL ITS MINIMUM INFORMATION VALUES GREATER THAN ANY MAXIMUM INFORMATION VALUE FOR THE DOMINATED CONCEPT
- SUCH CONCEPTS NEED NO FURTHER CONSIDERATION

350479-67 (6-27 83)

In analyzing the competing collection concepts, there occasionally will be a case where the performance of one of the candidate concepts is so low relative to other concepts that it no longer needs to be considered. A concept, A, is said to be stochastically or probabilistically dominated if no matter what values the collection performance variables take, there is at least one other concept, B, such that for every information requirement, Rj, the minimum performance range associated with B exceeds the maximum performance associated with A. Since the goal is to find the single most effective concept, no further consideration needs to be given to a dominated concept.*

As shown in the preceeding table on performance ranges, concepts 2 and 4 are completely dominated by concepts 1 and 3. Therefore John will no longer consider concepts 2 and 4 in his analysis.

*Except if the ultimate use is in cost-effectiveness trade off. However, this is not the problem presently being considered.

The ultimate goal of this methodology should not be the achievement of a stochastically dominant solution. While this is desirable from the decision maker's viewpoint, his task is made easier, the non-linear aspects of the problem does not quarantee the existence of a dominant solution. Therefore, stochastic dominance is not used as a goal for solution selection, but instead serves as a means of problem simplification by allowing for the identification and elimination of totally unacceptable solutions. If a single, dominant solution is not found, the decision maker must then view the decision in terms of required levels of performance, as well as risk aversion or acceptance preferences. Using these two measures, alternatives which do not dominate each other can be distinguished and a solution selected.

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PROBABILISTIC ANALYSIS

HUGHES

- A MONTE CARLO APPOACH IS USED TO DETERMINE THE COMPLETE PERFORMANCE SPECTRUM FOR EACH CONCEPT
- PROCEDURE
  - PERFORMANCE DISTRIBUTION RELATIVE TO EACH DATA REQUIREMENT ARE DEVELOPED FOR EACH NON-DOMINATED CONCEPT
  - GIVEN THE RELATIVE VALUE OF EACH DATA REQUIREMENT, THE PROBABILITY OF THE INFORMATION VALUE OBTAINED FOR EACH CONCEPT IS DETERMINED BY A MONTE CARLO ANALYSIS USING THOSE PERFORMANCE DISTRIBUTION
  - ALLOWS CONFIDENCE ASSESSMENT

350479 63-6 27 63)

To further compare the remaining concepts, it is necessary to get more insight into how the value of the information they collect varies over the performance ranges relative to each information collection requirement. This is done by developing distributions that describe the probability of achieving various values of information. These will allow the analyst to do confidence assessments.

The first step in performing a probabilistic analysis is to roughly determine the performance distribution relative to each information requirement for each candidate collection concept still under consideration. The specification of these distributions can be a simple and as gross as merely specifying a handful of points (for example, the minimum performance level, the 10th percentile, 30th percentile, the 50th percentile (expected performance), 70th percentile, 90th percentile, and the maximum performance level). In John's example, all the performance distributions were assumed to be uniform, that is, given

a = minimum performance level
b = maximum performance level

then if $P(v)$ is the probability of collecting information with at least a value of v,

$$P(v) = (v-a)/(b-a), \quad a \le v \le b$$
$$P(v) = 0, \text{ otherwise}$$

and if $p(v)$ is the probability that the information collected had exactly a value of v,

$$p(v) = 1/(b-a), \quad a \le v \le b$$
$$p(v) = 0, \text{ otherwise}$$

Another distribution which also could have been selected is the normal distribution. The key, however, is that it is not necessary to specify a "classic" distribution if there is not one that represents the collection concept's performance relative to a particular information requirement; a simple estimate based on expert judgement is sufficient.

It is important to note that while these performance distributions can be developed for every information requirement, those requirements which the performance analysis has shown to have virtually no impact on the overall value can simply be left at their expected value. This saves the analyst the extra work of defining distributions for those requirements.

Once all the necessary performance distributions have been defined, they are used with Monte Carlo techniques to derive the probabilistic performance of the value of the information collected for each remaining candidate collection concept. The basic approach is to select samples from the performance distributions, weight them with the relative value of the associated information requirement, adjusted to reflect any timeliness or survivability considerations, and add them all together to get a sample of the distribution for the value of the information collected. More formally,

given

$X_j(i)$, the ith sample from the performance of jth information requirement,

V_j, the relative value of the jth information requirement,

n, the number of information requirements

Y_i, the ith sample from the information value distribution

then

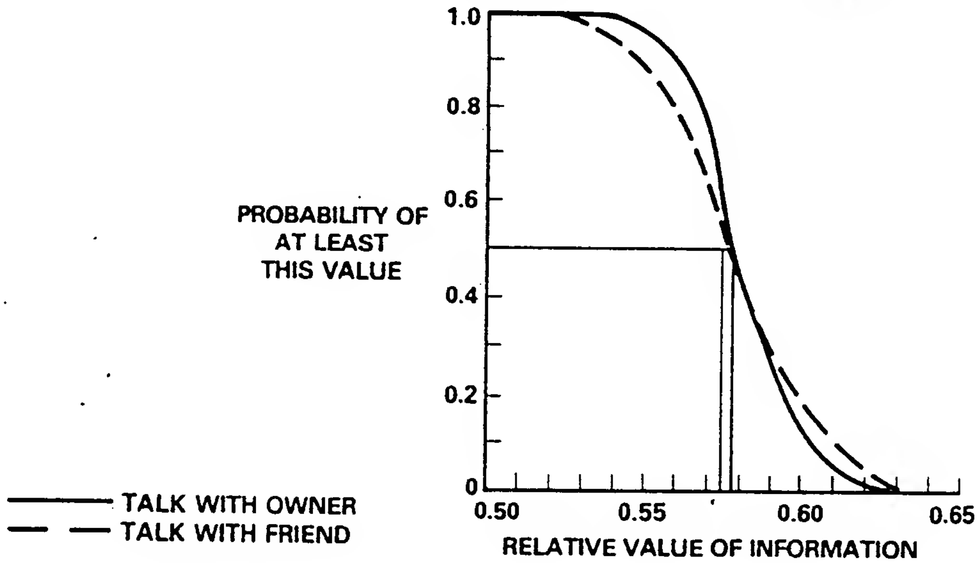
$$Y_i = \sum_{j=1}^{n} V_j * X_j(i)$$

The adjoining graphs illustrate the results of the probabilistic analysis for John's problem. The top figure is a graph of the probability of achieving a guaranteed value of information. Note that although the curves are close, there is a difference which influences which one should be selected. If John is risk-adverse, he should talk with the owner because there is less chance of getting the lowest possible values; if however John is risk-immune, he should instead talk with his friend because there is a chance he will collect a higher value.

The differences between the two concepts are even more clearly highlighted in the lower figure. Talking with the owner brings more consistent results, there is less variance. Talking with a friend could just as easily give you a lower information value as a higher relative to that which can typically be achieved by the other concept.

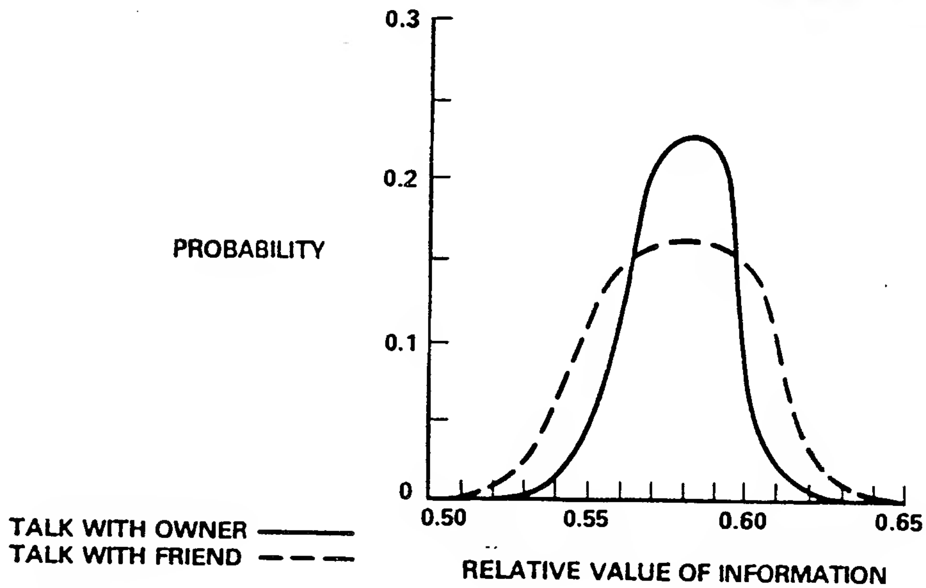
LIKELIHOOD OF COLLECTION

HUGHES



PERFORMANCE COMPARISON

HUGHES



DECISION MAKER REVIEW

HUGHES

AT ANY POINT IN THE ANALYSIS, THE ENTIRE PROCESS ACCOMPLISHED TO THAT POINT IS COMPLETELY ACCESSIBLE TO

- REVIEW
- QUESTIONING
- RE-ASSESSMENT

ALL ASSUMPTIONS ARE OUT IN THE OPEN AND THE ANALYSIS PATHS ARE READILY TRACEABLE

One of the strengths of the methodology is the generation of traceable paths through the analysis. Since every assumption is documented and the analytic process is straightforward and completely visible, the study is accessible at any point for review. This means the decision maker does not need to rely solely on an intuitive understanding of the problem which is especially important when the results are to be communicated and perhaps defended to others. The methodology itself provides a structure for discussing the analysis and the results and, if necessary, for defining at what point re-assessment may be necessary. Additionally, if re-evaluation is required, any new assumptions can be readily substituted for old with retention of much of the remaining structure.

To purchase a home, John is going to need financial assistance from his parents; so when he finished his collection concept analysis, he took it to his parents for review. Overall, they understood and agreed with what John had done. They did, however, feel that if this house was to be in a sense an investment for them as well, the weights on the information value tree should reflect more of an emphasis on the investment issues. Their recommendation was that the consensus tree should be recalculated, but this time with the following weights

- 3 for Sue's values
- 2 for Mary's values
- 1 for Gary's values

The revised calculation of the consensus weights is shown in the adjoining table. The basic formula used was

```
W*(i)     = ith consensus weight
          = (1/6) * [2 * (Mary's ith weight) +
                     3 * (Sue's ith weight) +
                     1 * (Gary's ith weight) ]
```

REVIEW OF JOHN'S ANALYSIS

HUGHES

AFTER JOHN COMPLETED HIS ANALYSIS HE SHOWED IT TO HIS PARENTS SINCE HE NEEDS THEIR HELP TO FINANCE SUCH A PURCHASE

IN GENERAL THEY AGREED WITH WHAT HE HAD DONE. THEY FELT HOWEVER THAT THE WEIGHTS ON JOHN'S TREE SHOULD BE ADJUSTED TO REFLECT MORE OF THEIR EMPHASIS ON THE FUTURE WORTH OF THIS INVESTMENT

THEIR SUGGESTION WAS THAT THEIR JOINT CONSENSUS TREE SHOULD BE CALCULATED WITH

3 FOR SUE'S WEIGHTS
2 FOR MARY'S WEIGHTS
1 FOR GARY'S WEIGHT

380478-37 (6-27-83)

	MARY	SUE	GARY	CONSENSUS	RELATIVE TO TREE
EXPERT PREFERENCES/WEIGHTS	2	3	1	–	–
FUNCTIONAL NEEOS	0.35	0.15	0.25	0.233	0.233
BIG ENOUGH	0.60	0.30	0.40	0.483	0.113
BEDROOMS	0.50	0.40	0.50	0.450	0.051
SO FOOTAGE	0.50	0.60	0.50	0.550	0.062
LOCATION	0.20	0.70	0.60	0.517	0.120
SCHOOLS	0.40	0.60	0.45	0.508	0.061
WORK	0.40	0.10	0.20	0.217	0.026
SHOPPING	0.20	0.30	0.35	0.275	0.033
SUPPORT REOUIRED	0.50	0.25	0.25	0.333	0.333
MAINTAINABILITY	0.80	0.70	0.50	0.700	0.233
AMT OF YARO WORK	0.40	0.30	0.40	0.350	0.082
AGE OF HOUSE	0.60	0.70	0.60	0.650	0.151
DURABILITY	0.20	0.30	0.50	0.300	0.100
CONOITION OF SIMILAR	0.70	0.70	0.60	0.683	0.069
DISASTER VULNERABILITY	0.30	0.30	0.40	0.317	0.031
INVESTMENT POTENTIAL	0.15	0.60	0.50	0.434	0.434
IMMEDIATE AFFORDABILITY	0.45	0.20	0.40	0.317	0.138
DOWN PAYMENT	0.50	0.50	0.50	0.500	0.069
CLOSING COSTS	0.50	0.50	0.50	0.500	0.069
CONTINUING AFFOROABILITY	0.45	0.20	0.40	0.317	0.138
BASIC MONTHLY	0.40	0.40	0.35	0.392	0.054
INTEREST	0.40	0.40	0.40	0.400	0.055
PROJ. ASSESSMENTS	0.20	0.20	0.25	0.208	0.029
FUTURE WORTH	0.10	0.60	0.20	0.366	0.158
EXP. APPRECIATION	0.30	0.60	0.50	0.483	0.076
PLANNED OEVELOPMENT	0.70	0.40	0.50	0.517	0.082

380478-38 (6-27-83)

HUGHES

REVISED CALCULATION OF CONSENSUS WEIGHTS

COMPARISON OF DATA PRIORITIES

HUGHES

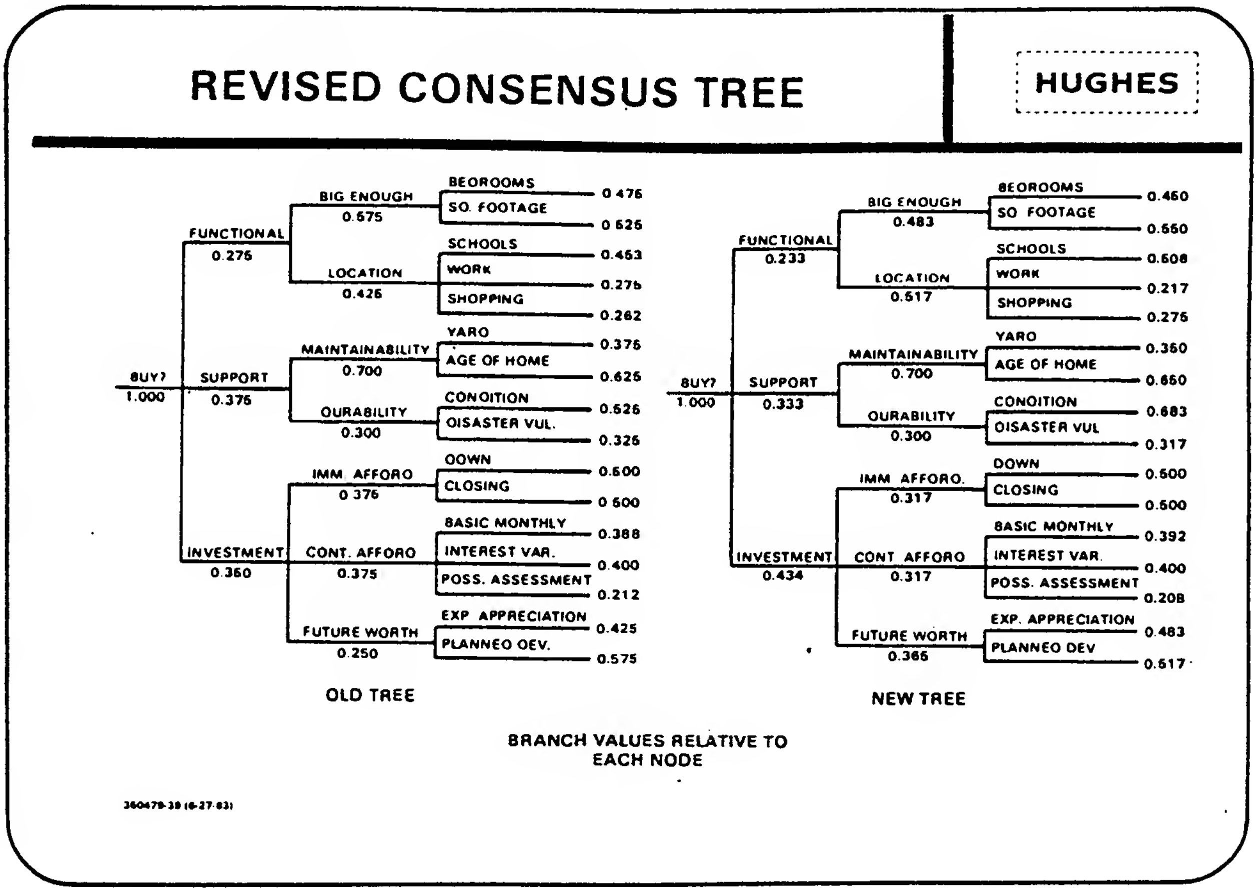
AGE OF HOUSE AMOUNT OF YARD WORK SQUARE FOOTAGE CONDITION OF SIMILAR HOUSES	AGE OF HOUSE PLANNED DEVELOPMENTS AMOUNT OF YARD WORK EXPECTED APPRECIATION
NUMBER OF BEDROOMS DOWN PAYMENT CLOSING COSTS LOCATION RELATIVE TO SCHOOLS	DOWN PAYMENT CLOSING COSTS CONDITION OF SIMILAR HOUSES SQUARE FOOTAGE
INTEREST VARIANCE BASIC MONTHLY PAYMENT PLANNED DEVELOPMENTS DISASTER VULNERABILITY	LOCATION RELATIVE TO SCHOOLS INTEREST VARIANCE BASIC MONTHLY PAYMENT NUMBER OF BEDROOMS
EXPECTED APPRECIATION LOCATION RELATIVE TO WORK LOCATION RELATIVE TO SHOPPING POSSIBLE ASSESSMENTS	LOCATION RELATIVE TO SHOPPING DISASTER VULNERABILITY POSSIBLE ASSESSMENTS LOCATION RELATIVE TO WORK

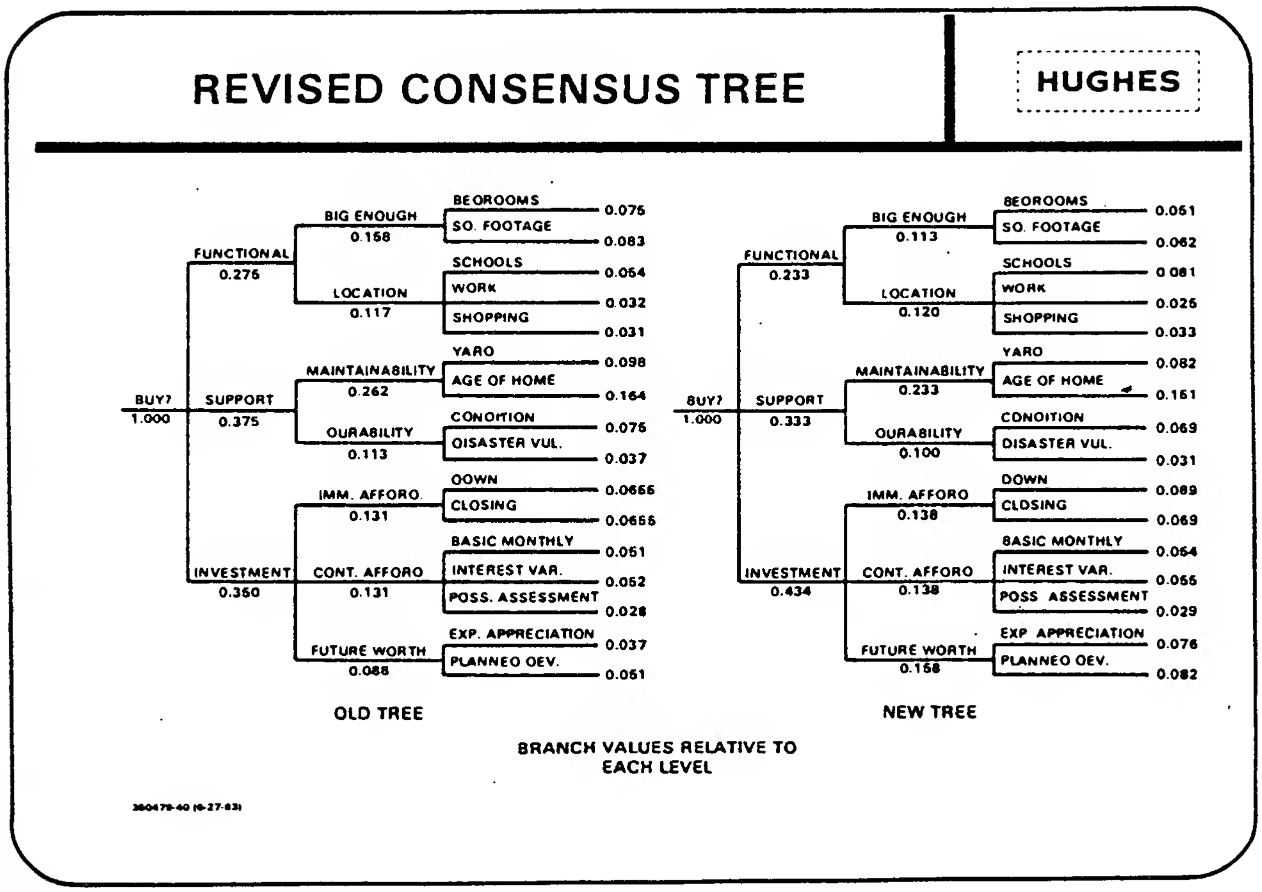
350479-54 (6-27-83)

The revised consensus trees, both the basic (with branch weights relative to the preceeding node) and the modified (with branch weights relative to the level), are presented on the next page in comparison to the original consensus trees. Note how the emphasis has moved towards the investment issues in general and the future worth in particular.

In the above table are ranked lists of collection requirements, one reflecting the original analysis, one reflecting this revised analysis. Some of the collection requirements have been significantly re-ordered, especially

- square footage
- number of bedrooms
- planned developments
- expected appreciation


REVISED CONSENSUS TREE
HUGHES
BUY? 1.000
FUNCTIONAL 0.275
BIG ENOUGH 0.575
BEDROOMS 0.475
SQ. FOOTAGE 0.525
LOCATION 0.425
SCHOOLS 0.463
WORK 0.275
SHOPPING 0.262
SUPPORT 0.375
MAINTAINABILITY 0.700
YARD 0.375
AGE OF HOME 0.625
DURABILITY 0.300
CONDITION 0.525
DISASTER VUL. 0.325
INVESTMENT 0.350
IMM. AFFORD 0.375
DOWN 0.500
CLOSING 0.500
CONT. AFFORD 0.375
BASIC MONTHLY 0.388
INTEREST VAR. 0.400
POSS. ASSESSMENT 0.212
FUTURE WORTH 0.250
EXP. APPRECIATION 0.425
PLANNED DEV. 0.575
OLD TREE
BUY? 1.000
FUNCTIONAL 0.233
BIG ENOUGH 0.483
BEDROOMS 0.450
SQ. FOOTAGE 0.550
LOCATION 0.517
SCHOOLS 0.508
WORK 0.217
SHOPPING 0.275
SUPPORT 0.333
MAINTAINABILITY 0.700
YARD 0.350
AGE OF HOME 0.650
DURABILITY 0.300
CONDITION 0.683
DISASTER VUL 0.317
INVESTMENT 0.434
IMM. AFFORD. 0.317
DOWN 0.500
CLOSING 0.500
CONT. AFFORD 0.317
BASIC MONTHLY 0.392
INTEREST VAR. 0.400
POSS. ASSESSMENT 0.208
FUTURE WORTH 0.365
EXP. APPRECIATION 0.483
PLANNED DEV 0.517
NEW TREE
BRANCH VALUES RELATIVE TO EACH NODE
360479-39 (6-27-83)


REVISED CONSENSUS TREE
HUGHES
BUY? 1.000
FUNCTIONAL 0.275
BIG ENOUGH 0.158
BEDROOMS 0.075
SQ. FOOTAGE 0.083
LOCATION 0.117
SCHOOLS 0.054
WORK 0.032
SHOPPING 0.031
SUPPORT 0.375
MAINTAINABILITY 0.262
YARD 0.098
AGE OF HOME 0.164
DURABILITY 0.113
CONDITION 0.075
DISASTER VUL. 0.037
INVESTMENT 0.350
IMM. AFFORD. 0.131
DOWN 0.0656
CLOSING 0.0656
CONT. AFFORD 0.131
BASIC MONTHLY 0.051
INTEREST VAR. 0.052
POSS. ASSESSMENT 0.028
FUTURE WORTH 0.088
EXP. APPRECIATION 0.037
PLANNED DEV. 0.051
OLD TREE
BUY? 1.000
FUNCTIONAL 0.233
BIG ENOUGH 0.113
BEDROOMS 0.051
SQ. FOOTAGE 0.062
LOCATION 0.120
SCHOOLS 0.061
WORK 0.026
SHOPPING 0.033
SUPPORT 0.333
MAINTAINABILITY 0.233
YARD 0.082
AGE OF HOME 0.151
DURABILITY 0.100
CONDITION 0.069
DISASTER VUL. 0.031
INVESTMENT 0.434
IMM. AFFORD 0.138
DOWN 0.069
CLOSING 0.069
CONT. AFFORD 0.138
BASIC MONTHLY 0.054
INTEREST VAR. 0.055
POSS ASSESSMENT 0.029
FUTURE WORTH 0.158
EXP APPRECIATION 0.076
PLANNED DEV. 0.082
NEW TREE
BRANCH VALUES RELATIVE TO EACH LEVEL
360479-40 (6-27-83)

Having completed the revised consensus tree, John can now procede to the assessment of the potential collection concepts. Since his parents had no disagreement with the information performance factors that were developed in the original analysis, the revised performance analysis follows much as before: relative to each collection concept, the revised relative values of information for each information requirement are multiplied by the expected performance of the concept and the resulting expected information values are summed to determine the overall expected information value collected. The results of this analysis are shown in the top figure of the next page. Once again it appears talking with the city or checking the newspaper fall short; this time, however, the margin between talking with his real estate friend and talking with the owner is greater. So the preliminary assessment is the third collection concept appears to be the most effective.

To investigate this preference more thoroughly, John again considered the impact on the overall value of the information collected relative to each collection concept by evaluating each information requirement at its minimum and maximum levels of performance. The results, shown in the figure at the bottom of the next page, indicate that talking with the real estate friend appears to stochastically dominate all the other candidate collection concepts, however the issue of timeliness remains to be accounted for.

EXPECTED PERFORMANCE

HUGHES

INFORMATION SOURCE	EXP. VALUE
TALK WITH THE OWNER	0.53
TALK WITH THE CITY	0.26
TALK WITH FRIEND (AGENT)	0.61
CHECK NEWSPAPER	0.14

380479-41 (6-27-83)

REVISED PERFORMANCE ANALYSIS

HUGHES

	TALK WITH OWNER		TALK WITH CITY		TALK WITH FRIEND (AGENT)		CHECK NEWSPAPER	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
NUMBER OF BEDROOMS	0.53	0.53	0.26	0.26	0.61	0.62	0.14	0.14
SQUARE FOOTAGE	0.53	0.53	0.26	0.26	0.60	0.62	0.13	0.15
SCHOOLS (LOCATION)	0.52	0.54	0.25	0.27	0.60	0.62	0.13	0.14
WORK (LOCATION)	0.53	0.53	0.26	0.26	0.60	0.62	0.14	0.14
SHOPPING (LOCATION)	0.52	0.54	0.26	0.26	0.60	0.62	0.13	0.14
AMOUNT OF YARD WORK	0.52	0.54	0.26	0.26	0.61	0.61	0.14	0.14
AGE OF HOME	0.52	0.54	0.23	0.29	0.58	0.64	0.11	0.16
CONDITION OF SIMILAR HOMES	0.52	0.55	0.26	0.26	0.60	0.63	0.14	0.14
DISASTER VULNERABILITY	0.53	0.54	0.26	0.26	0.61	0.62	0.14	0.14
DOWN PAYMENT	0.53	0.53	0.26	0.26	0.61	0.62	0.14	0.14
CLOSING COSTS	0.53	0.53	0.26	0.26	0.60	0.63	0.14	0.14
BASIC MONTHLY PAYMENT	0.53	0.53	0.26	0.26	0.61	0.62	0.14	0.14
PROJECTED INTEREST VARIANCE	0.53	0.53	0.26	0.26	0.60	0.62	0.14	0.14
POSSIBLE ASSESSMENTS	0.53	0.54	0.26	0.26	0.61	0.62	0.14	0.14
EXPECTED APPRECIATION	0.52	0.54	0.25	0.27	0.60	0.62	0.14	0.14
PLANNED DEVELOPMENTS	0.52	0.54	0.25	0.27	0.60	0.62	0.13	0.14

380479-42 (6-27-83)

As in the original analysis, John must adjust the assessment of the third collection concept, talking with the real estate friend, to reflect the two week delay in collecting any information. The same estimate is used for the discount rate, 5%, which is a factor of (1/1.05) or approximately 0.95. This translates into a reduction of about 3 to 4% in the performance factors for this collection concept as shown in the figure at the top of the next page.

A review of the ranges for the performance factors associated with each of the collection concepts, adjusted for timeliness considerations (see bottom figure on next page), indicates that while the concepts of talking with the city and checking in the newspaper are indeed stochastically dominated, there is a slight overlap for the other two. So before John completes his analysis, he will do a probabilistic analysis on these two remaining concepts.

REVISED PERFORMANCE ADJUSTMENTS

HUGHES

	ORIGINAL		DISCOUNTED	
	MIN.	MAX.	MIN.	MAX.
NUMBER OF BEDROOMS	.61	.62	.58	.59
SQUARE FOOTAGE	.60	.62	.57	.59
SCHOOLS (LOCATION)	.60	.62	.57	.59
WORK (LOCATION)	.60	.62	.57	.59
SHOPPING (LOCATION)	.60	.62	.57	.59
AMOUNT OF YARD WORK	.61	.61	.58	.58
AGE OF HOME	.58	.64	.55	.61
CONDITION OF SIMILAR HOMES	.60	.63	.57	.59
DISASTER VULNERABILITY	.61	.62	.58	.58
DOWN PAYMENT	.61	.62	.57	.59
CLOSING COSTS	.60	.63	.57	.59
BASIC MONTHLY PAYMENT	.61	.62	.58	.59
PROJECTED INTEREST VARIANCE	.60	.62	.57	.59
POSSIBLE ASSESSMENTS	.61	.62	.58	.59
EXPECTED APPRECIATION	.60	.62	.57	.59
PLANNED DEVELOPMENTS	.60	.62	.57	.59

350479-52 (6-27-83)

REVISED PERFORMANCE RANGES

HUGHES

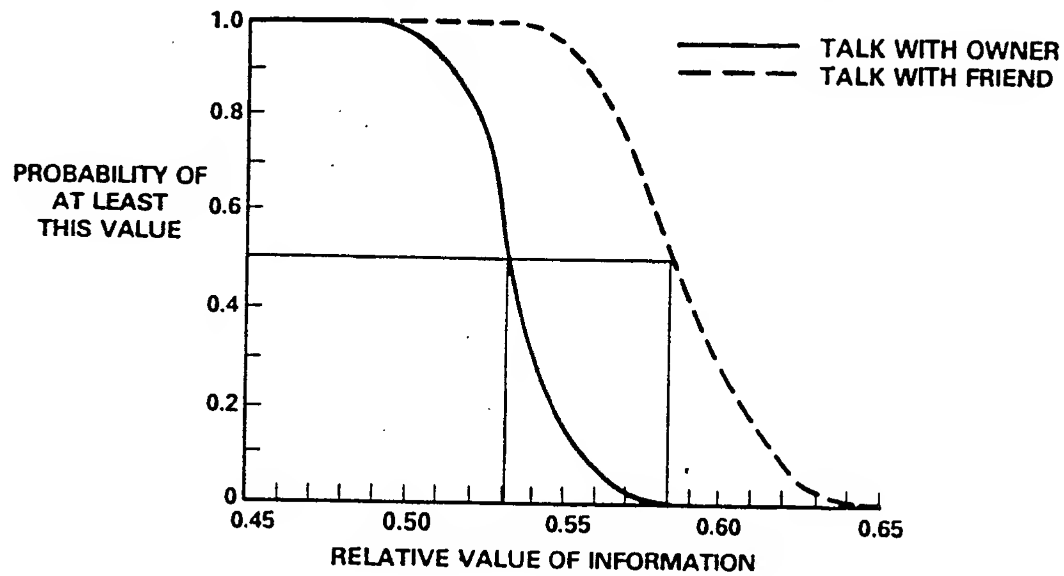
INFORMATION SOURCE	MIN. VALUE	MAX. VALUE
TALK WITH OWNER	.52	.55
TALK WITH CITY	.23	.29
TALK WITH FRIEND (AGENT)	.55	.61
CHECK NEWSPAPER	.11	.16

350479-50 (6-27-83)

The revised results of the probabilistic analysis are shown in the figures on the adjoining page. This time there is no question of which concept has the most effective performance. As the top figure shows, talking with the real estate friend consistently yields a likelihood for collecting a higher overall value of information. It is important to note, as the lower figure shows, this is completely independent of the range of performance of the two concepts, which was not changed; the third concept still has a greater possible variance in its performance. Because the relative weights of the information collected have changed, however, the overall expected performance of the two concepts has diverged, leaving the third concept the clear choice.

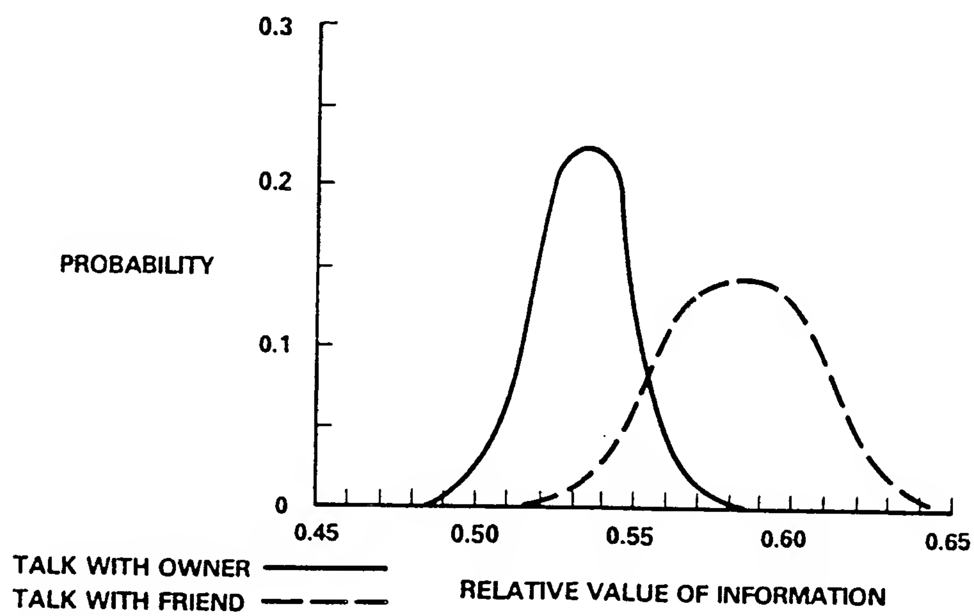
REVISED LIKELIHOOD OF COLLECTION

HUGHES



REVISED PERFORMANCE COMPARISON

HUGHES



CONTINUING APPLICABILITY

HUGHES

SIGNIFICANT AMOUNTS OF DATA ARE COMPILED TO SUPPORT THE METHODOLOGY, INCLUDING

- KEY PROBLEM ISSUES
- CONCEPT PERFORMANCE ESTIMATES
- TIMELINESS AND SURVIVABILITY ADJUSTMENT FACTORS

LARGE PORTIONS OF THAT DATA MAY BE REUSABLE

- RELATED PROBLEMS MAY USE SOME — EITHER DIRECTLY OR AS A GUIDELINE
- FOLLOW-ON WORK FOR PROBLEM UNDER STUDY MAY USE SUBSTANTIAL PORTIONS

As is readily apparent, the application of this methodology to collection systems problems is not a trivial exercise. Typical of all decision analysis approaches, it requires the compilation of a significant amount of data, including

- key issues to be investigated, including the information required to support the process and each piece's relative weight
- evaluation of experts
- collection concept performance -- not just at the likely or expected level but also minimum and maximum levels and, in some cases, an approximation of the entire performance distribution
- quantification of impacts of discounting effects due to timeliness considerations and compounding effects due to survivability considerations

As such, this approach should be reserved for large, resource-critical decisions.

However, the usefulness of much of this data does not end with the study. Related problems may be able to use portions of the performance estimates or large subsections of the tree either intact or as a template or prototype. Similarly, there may be follow-on applications that reconsider some of the basic elements and leave the rest essentially the same. Examples might be the evaluation of an additional concept or the availability of a new expert or the analysis of the same problem but from a different point in time.

Instead of initiating an information collection effort at the time the original study was done, John just did some preliminary investigation and delayed collecting everything else. A month later he decided to go ahead and seriously analyze the house in question. But the evaluation he would have done before was not completely correct any longer as he had already collected a certain amount of information (such as the number of bedrooms, the square footage, the relative distances, etc.). Therefore, collecting it again had significantly reduced importance. So he went back to his experts for updated weights. New consensus weights were calculated using the same evaluation of the experts as was done for the revised weights

- 3 for Sue's value
- 2 for Mary's value
- 1 for Gary's value

The updated weights supplied by the experts as well as the new consensus weights are shown in the top figure on the next page. These weights produce a new ordering of information. Again, a signficant re-ranking has taken place, especially for

- age of house
- amount of yard work
- square footage
- number of bedrooms
- planned developments
- expected appreciation
- disaster vulnerability
- possible assessments

UPDATED CALCULATION OF CONSENSUS WEIGHTS

HUGHES

	MARY	SUE	GARY	CONSENSUS	RELATIVE TO TREE
EXPERT PREFERENCES/WEIGHTS	2	3	1	–	–
FUNCTIONAL NEEDS	0.15	0.05	0.10	0.092	0.092
BIG ENOUGH	0.20	0.10	0.10	0.133	0.012
BEDROOMS	0.20	0.10	0.10	0.133	0.002
SQ. FOOTAGE	0.80	0.90	0.90	0.876	0.010
LOCATION	0.80	0.90	0.90	0.867	0.080
SCHOOLS	0.40	0.60	0.45	0.508	0.041
WORK	0.40	0.10	0.20	0.217	0.017
SHOPPING	0.20	0.30	0.35	0.275	0.022
SUPPORT REQUIRED	0.35	0.15	0.20	0.225	0.225
MAINTAINABILITY	0.40	0.30	0.20	0.317	0.071
AMT OF YARD WORK	0.60	0.60	0.60	0.600	0.043
AGE OF HOUSE	0.40	0.40	0.90	0.400	0.028
DURABILITY	0.60	0.70	0.80	0.683	0.154
CONDITION OF SIMILAR	0.50	0.40	0.35	0.425	0.065
DISASTER VULNERABILITY	0.50	0.60	0.65	0.575	0.089
INVESTMENT POTENTIAL	0.50	0.80	0.70	0.683	0.683
IMMEDIATE AFFORDABILITY	0.45	0.20	0.40	0.317	0.216
DOWN PAYMENT	0.50	0.50	0.50	0.500	0.108
CLOSING COSTS	0.50	0.50	0.50	0.500	0.108
CONTINUING AFFORDABILITY	0.45	0.20	0.40	0.317	0.216
BASIC MONTHLY	0.35	0.30	0.30	0.317	0.069
INTEREST	0.35	0.30	0.35	0.325	0.070
PROJ ASSESSMENTS	0.30	0.40	0.35	0.358	0.079
FUTURE GROWTH	0.10	0.60	0.20	0.366	0.251
EXP APPRECIATION	0.30	0.60	0.50	0.483	0.121
PLANNED DEVELOPMENT	0.70	0.40	0.50	0.517	0.130

38098-3 (7-21-83)

UPDATED COMPARISON OF DATA PRIORITIES

HUGHES

INFORMATION REQUIREMENT	ORIGINAL	REVISED	UPDATED
AGE OF HOUSE	1	1	12
AMOUNT OF YARD WORK	2	3	10
SQUARE FOOTAGE	3	8	15
CONDITION OF SIMILAR HOUSES	4	7	9
NUMBER OF BEDROOMS	5	12	16
DOWN PAYMENT	6	5	3
CLOSING COSTS	7	6	4
LOCATION RELATIVE TO SCHOOLS	8	9	11
INTEREST VARIANCE	9	10	7
BASIC MONTHLY PAYMENT	10	11	8
PLANNED DEVELOPMENTS	11	2	1
DISASTER VULNERABILITY	12	14	5
EXPECTED APPRECIATION	13	4	2
LOCATION RELATIVE TO WORK	14	16	14
LOCATION RELATIVE TO SHOPPING	15	13	13
POSSIBLE ASSESSMENTS	16	15	6

38098-4 (7-21-83)

With the updated consensus tree, John procedes to the collection concept evaluation phase. Assuming the same set of collection concepts with the same performance characteristics, an analysis is done of the updated performance, generating overall expected values for the information collected for each concept. The results are presented at the top of the next page. This time talking with the friend appears to be significantly more effective than any other concept.

To verify that talking with the friend is the concept to be chosen, John considered for a third time the impact on overall value of information collected relative to each collection concept from evaluating each information requirement at its minimum and maximum levels of peformance. The results, shown in the figure at the bottom of the next page, demonstrate unequivically that the third concept stochastically dominates the entire set. Therefore, there is no need for further analysis.

UPDATED EXPECTED PERFORMANCE

HUGHES

INFORMATION SOURCE	EXP. VALUE
TALK WITH THE OWNER	0.35
TALK WITH THE CITY	0.29
TALK WITH FRIEND (AGENT)	0.62
CHECK NEWSPAPER	0.07

38096-6 (7-21-83)

UPDATED PERFORMANCE ANALYSIS

HUGHES

	TALK WITH OWNER		TALK WITH CITY		TALK WITH FRIEND (AGENT)		CHECK NEWSPAPER	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
NUMBER OF BEDROOMS	0.35	0.35	0.29	0.29	0.62	0.62	0.07	0.07
SQUARE FOOTAGE	0.35	0.35	0.29	0.29	0.62	0.63	0.06	0.07
SCHOOLS (LOCATION)	0.34	0.35	0.29	0.30	0.62	0.63	0.06	0.07
WORK (LOCATION)	0.34	0.35	0.29	0.29	0.62	0.63	0.07	0.07
SHOPPING (LOCATION)	0.34	0.35	0.29	0.29	0.62	0.63	0.06	0.07
AMOUNT OF YARD WORK	0.34	0.35	0.29	0.29	0.62	0.62	0.07	0.07
AGE OF HOME	0.35	0.35	0.29	0.30	0.62	0.63	0.06	0.07
CONDITION OF SIMILAR HOMES	0.33	0.36	0.29	0.29	0.61	0.64	0.07	0.07
DISASTER VULNERABILITY	0.34	0.35	0.28	0.30	0.61	0.64	0.07	0.07
DOWN PAYMENT	0.35	0.35	0.29	0.29	0.61	0.64	0.07	0.07
CLOSING COSTS	0.35	0.35	0.29	0.29	0.60	0.65	0.07	0.07
BASIC MONTHLY PAYMENT	0.35	0.35	0.29	0.29	0.62	0.63	0.07	0.07
PROJECTED INTEREST VARIANCE	0.35	0.35	0.29	0.29	0.61	0.64	0.07	0.07
POSSIBLE ASSESSMENTS	0.33	0.36	0.28	0.30	0.61	0.64	0.06	0.07
EXPECTED APPRECIATION	0.33	0.36	0.28	0.30	0.61	0.64	0.07	0.07
PLANNED DEVELOPMENTS	0.33	0.37	0.28	0.30	0.61	0.64	0.06	0.07

38096-6 (7-21-83)

DEMONSTRATION EFFORT

HUGHES

PROBLEM SELECTION CRITERIA

- CONSENSUS PROBLEM
  - IMPORTANCE OF PROBLEM MUTUALLY AGREED UPON
- MUST DEMONSTRATE ADAPTABILITY OF METHODOLOGY
- POSSESS A DEGREE OF COMPLEXITY TO EXERCISE ALL FACETS OF METHODOLOGY
- MUST ALLOW FOR APPLICATION OF SENSITIVITY ANALYSIS

360479-13 (6-27-83)

For the methodology developed to be of use to the analyst, it must be easily applied to the problems with which he/she is concerned. The preceding "toy" example is useful for illustration and education, but a demonstration effort on a more relevant problem to the collection concept analyst is needed. Care should be taken in choosing the topic of this effort so that maximum benefit may be achieved.

First of all, the problem should be of enough importance to warrant the effort undertaken and be of relevance to the community. The problem should have sufficient complexity to fully utilize and illustrate the documented methodology. Finally, the problem should be such that sensitivity analysis can be meaningfully employed and be used to show the conclusions and results such an effort makes possible.

In summary, the demonstration effort should show the power and usefulness of the methodology as well as its flexibility and adaptability. The remainder of this report documents what has been completed to date relative to this effort.

SAM PROBLEM

HUGHES

WHAT EFFECT WILL THE INTRODUCTION OF A SURFACE TO AIR MISSILE HAVE ON THE BALANCE OF POWER?

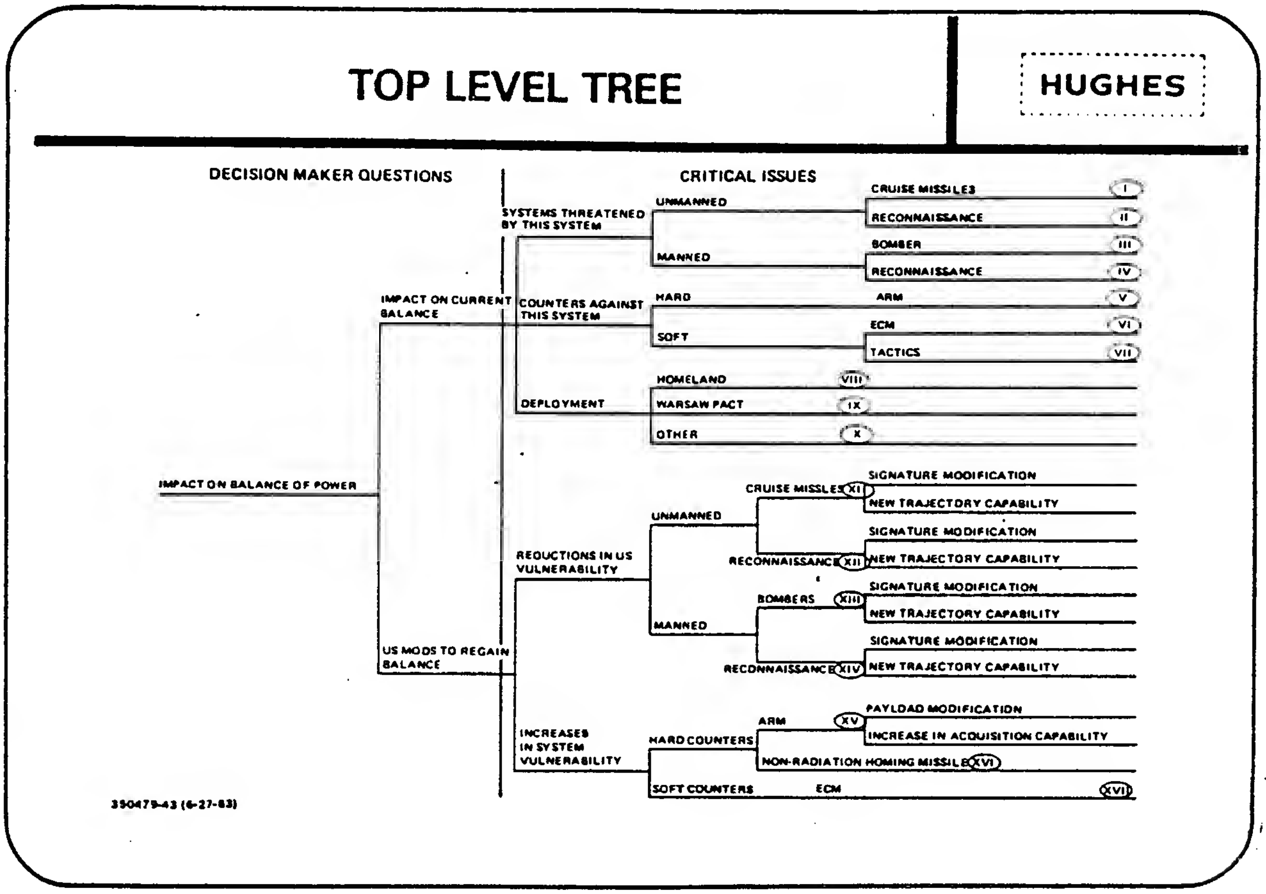
756079-47 (6-27-83)

The final stage of this analysis involves applying the developed methodology to a problem of interest to the intelligence community. By documenting this process, an example is available to the analyst to use as a guideline when performing additional analyses relating to collection concept concerns.

The problem chosen for illustration involves the information required to answer the question: What effect will the introduction of a surface to air missile (SAM) have on the balance of power? The point to keep in mind here is the frame of reference for the analysis. The methodology does not attempt to answer the question regarding the SAM and its effects, but instead the methodology determines the information required to answer the question. Given these requirements, the ability of a particular collection concept to collect the desired information can be evaluated and the rest of the sensitivity analysis completed.

As of the writing of this interim report, the SAM problem has been completed through the structuring of the information tree the structure is illustrated on the following pages. The remainder of the analysis will be documented in the final report of this study.

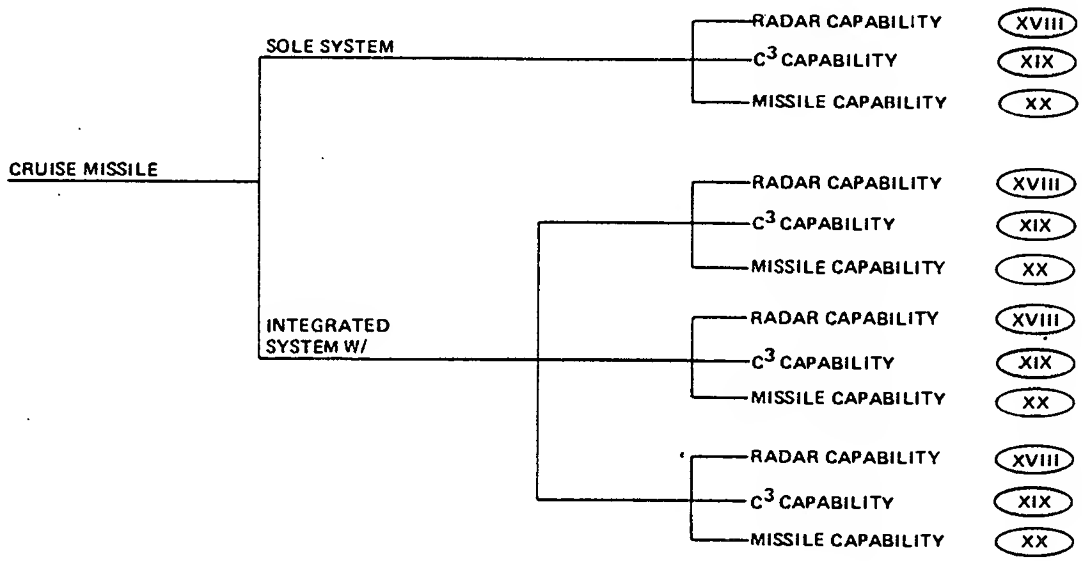
IV. B. INFORMATION TREE STRUCTURE



The top level tree for the SAM problem is shown above. The level of information is seen to get more specific with descent through the tree. For example, the first division is between direct threats posed by the system and modifications that could be undertaken to regain the balance of power. The tree expands in detail until the raw or collectable data level is reached. The tree structure in its entirety is illustrated on the following pages and is indexed using Roman numerals. The numerals refer to the figure number on which the continuation of the tree can be found. For example, the expansion of the homeland deployment tree can be found on Figure VIII.

I. CRUISE MISSILE

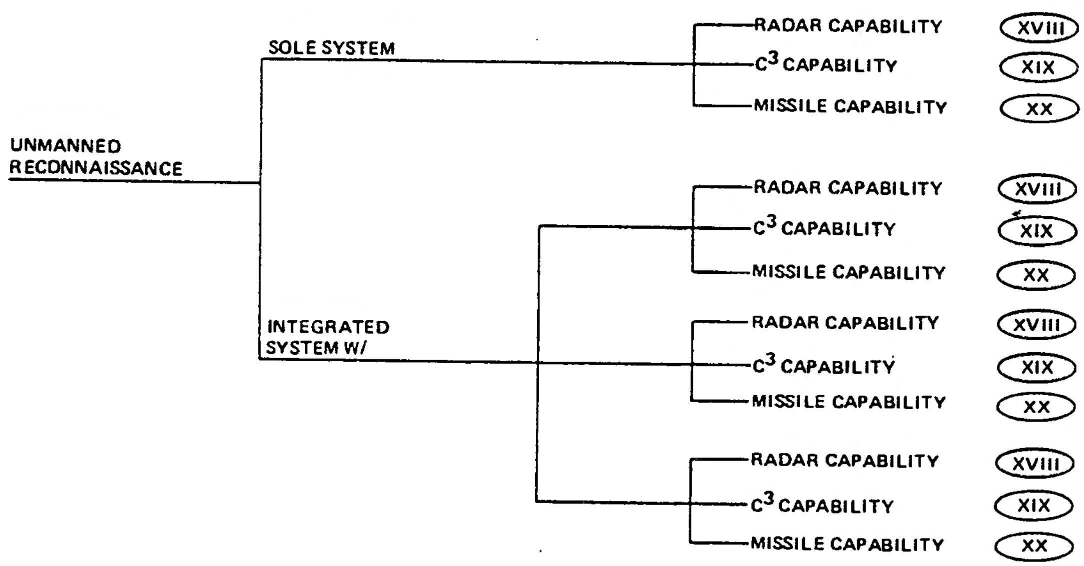
HUGHES



38098-7 (7-21-83)

II. UNMANNED RECONNAISSANCE

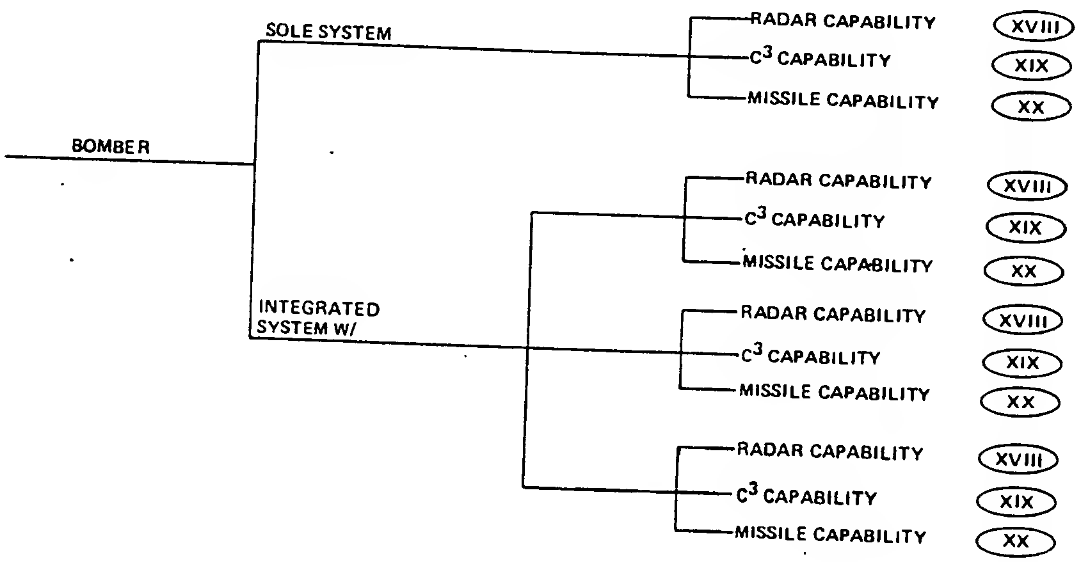
HUGHES



38098-8 (7-21-83)

III. BOMBER

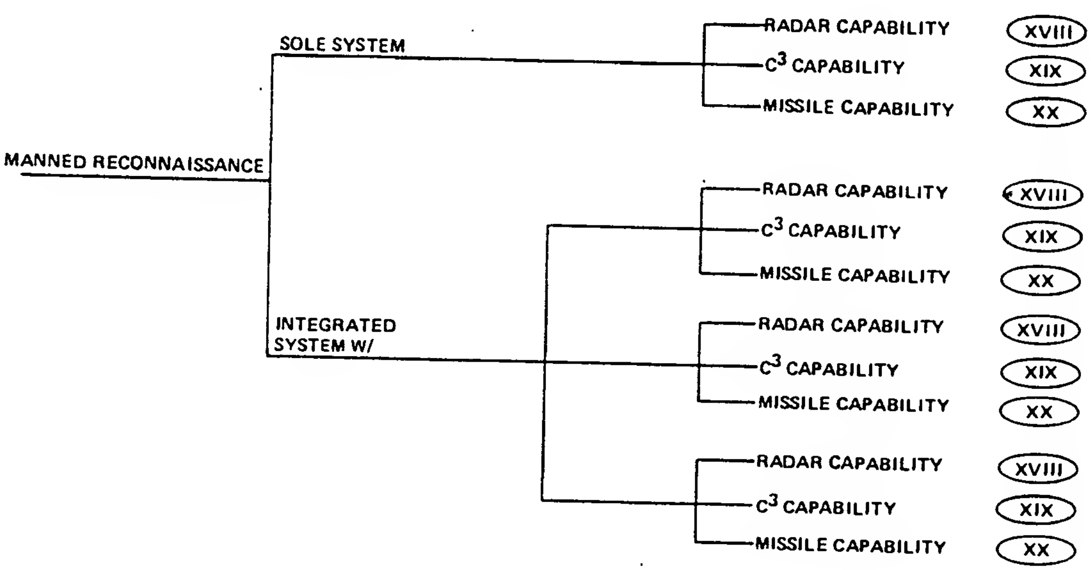
HUGHES



38098-9 (7-21-83)

IV. MANNED RECONNAISSANCE

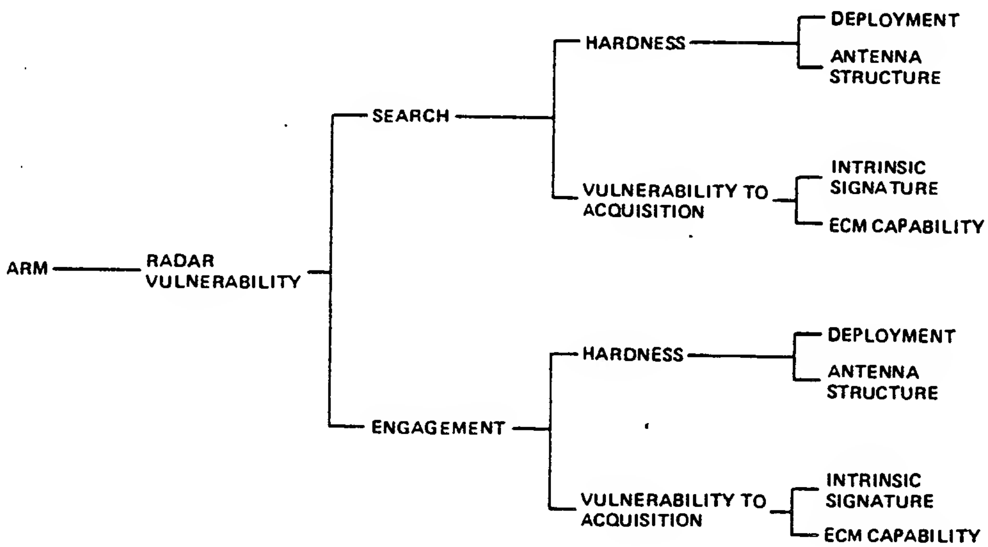
HUGHES



38098-10 (7-21-83)

V. HARD COUNTERS — ARM

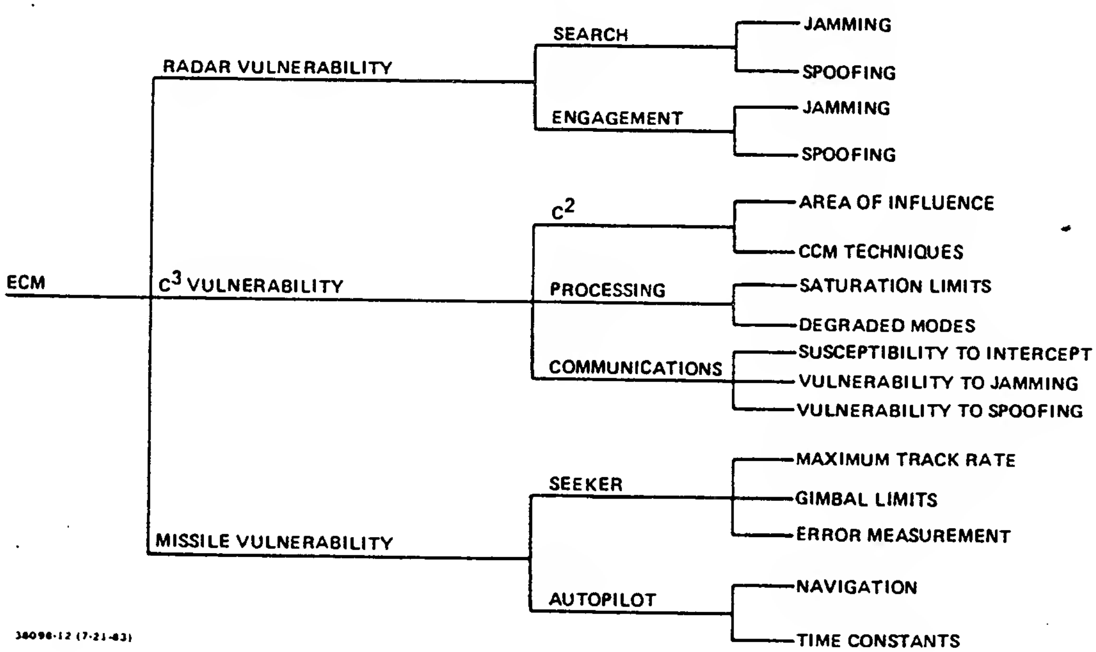
HUGHES



38098-11 (7-21-83)

VI. SOFT COUNTER — ECM

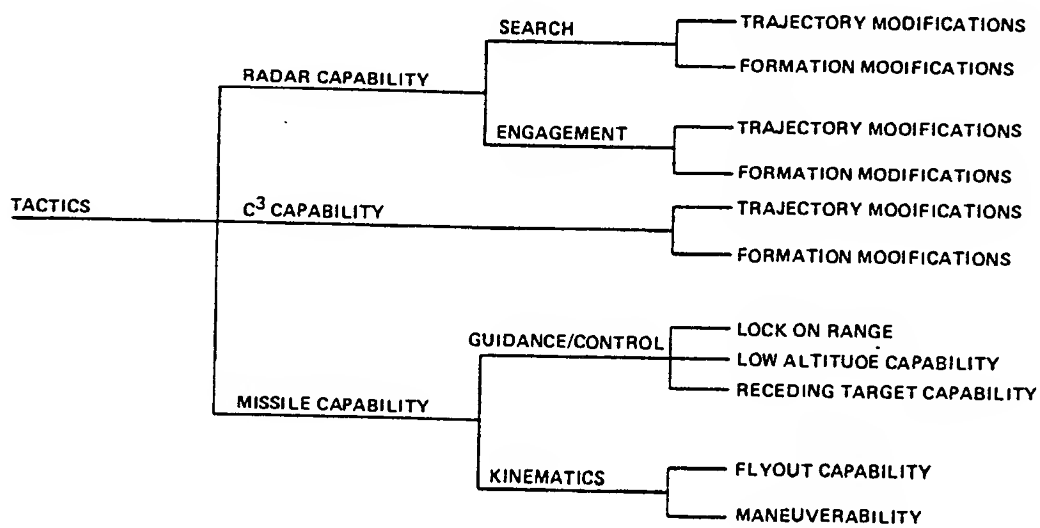
HUGHES



38098-12 (7-21-83)

VII. SOFT COUNTER — TACTICS

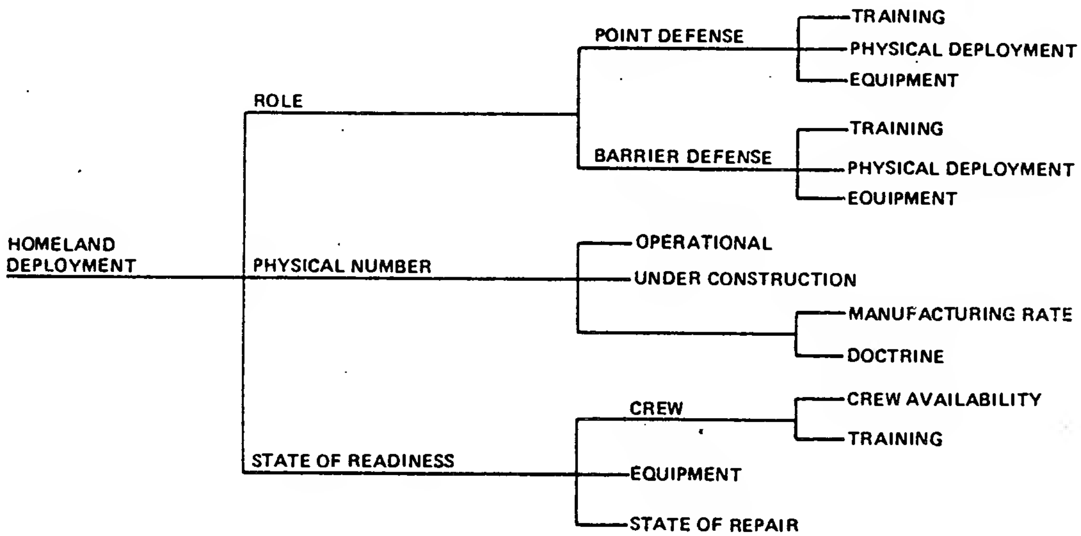
HUGHES



38098-13 (7-21-83)

VIII. HOMELAND DEPLOYMENT

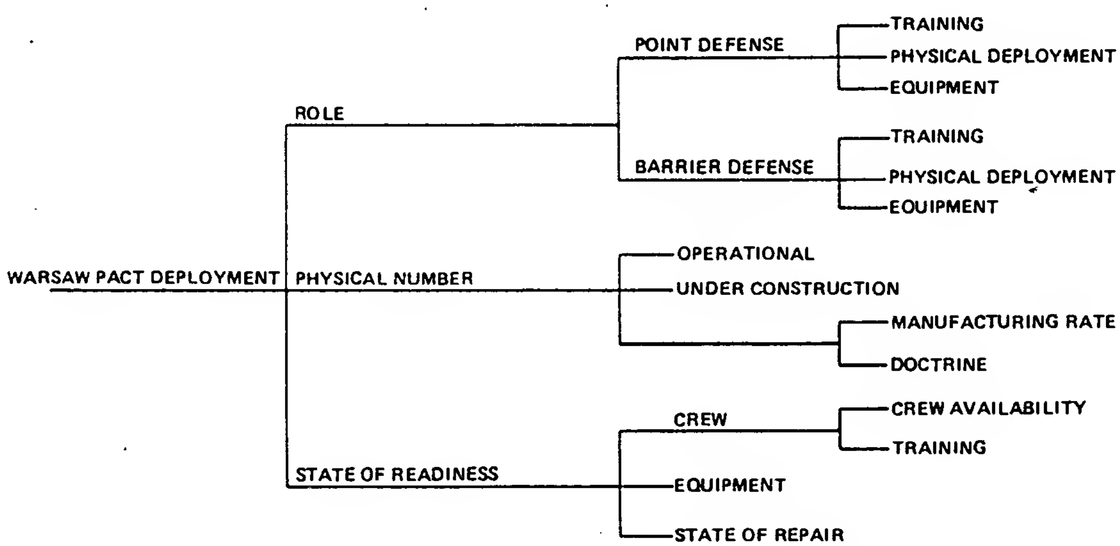
HUGHES



38098-14 (7-21-83)

IX. WARSAW PACT DEPLOYMENT

HUGHES

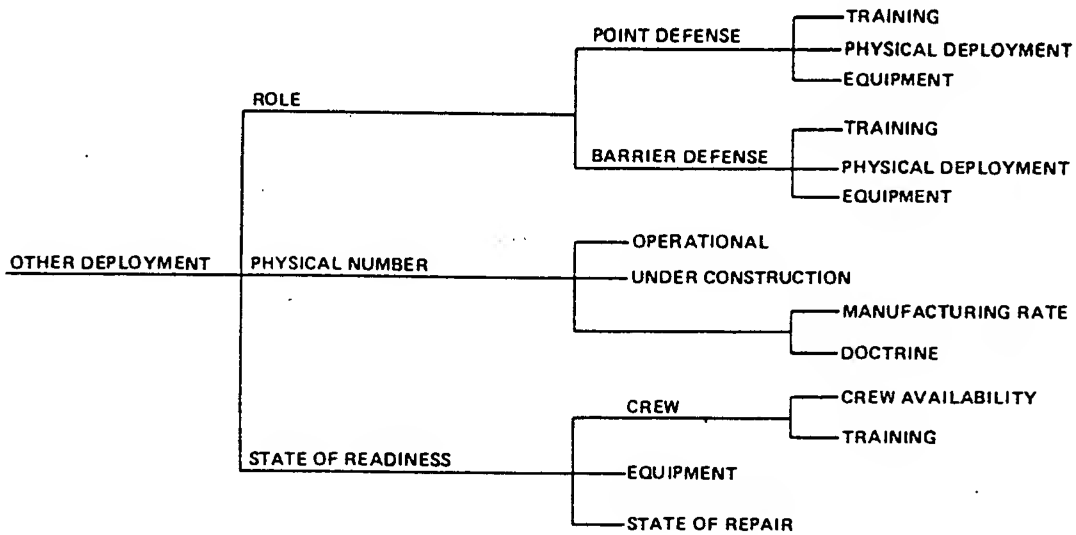


38098-15 (7-21-83)

Approved For Release 2003/09/29 : CIA-RDP86B00269R001300050001-1

X. OTHER DEPLOYMENT

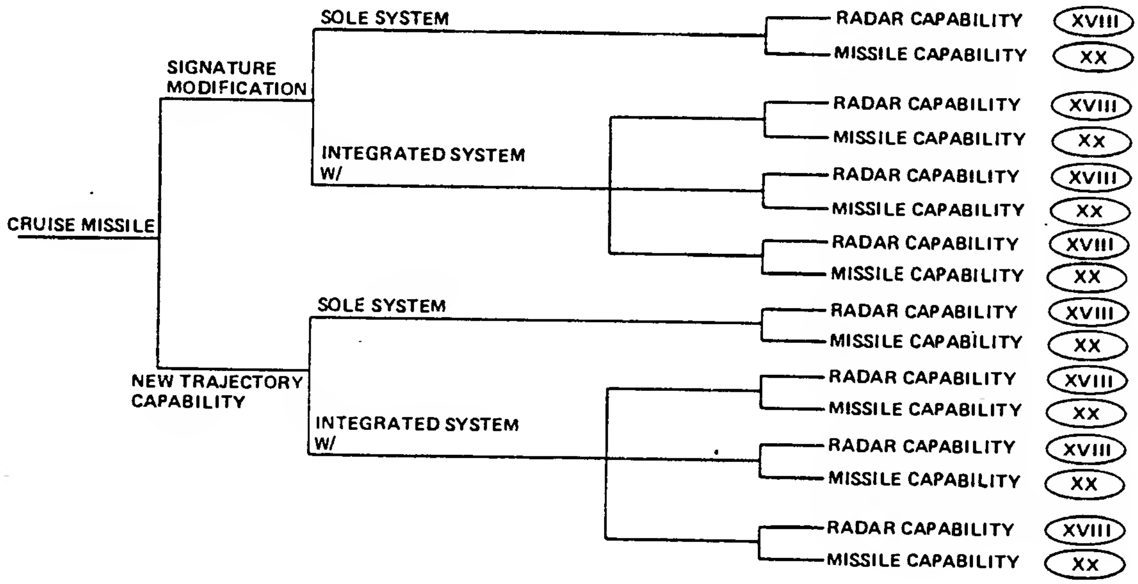
HUGHES



38098-16 (7-21-83)

XI. CRUISE MISSILE

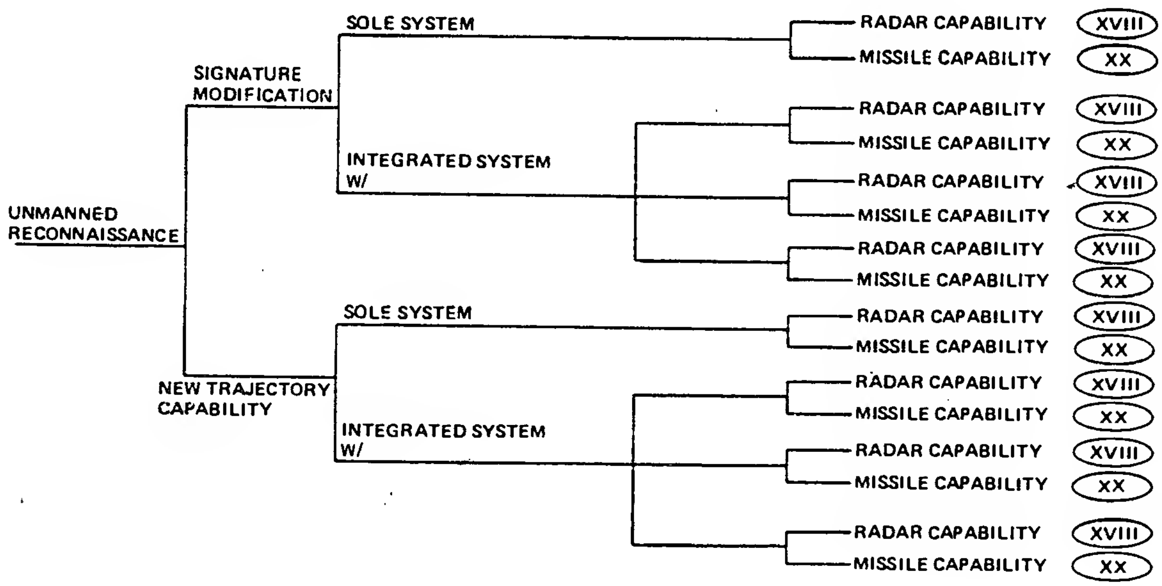
HUGHES



38098-17 (7-21-83)

XII. UNMANNED RECONNAISSANCE

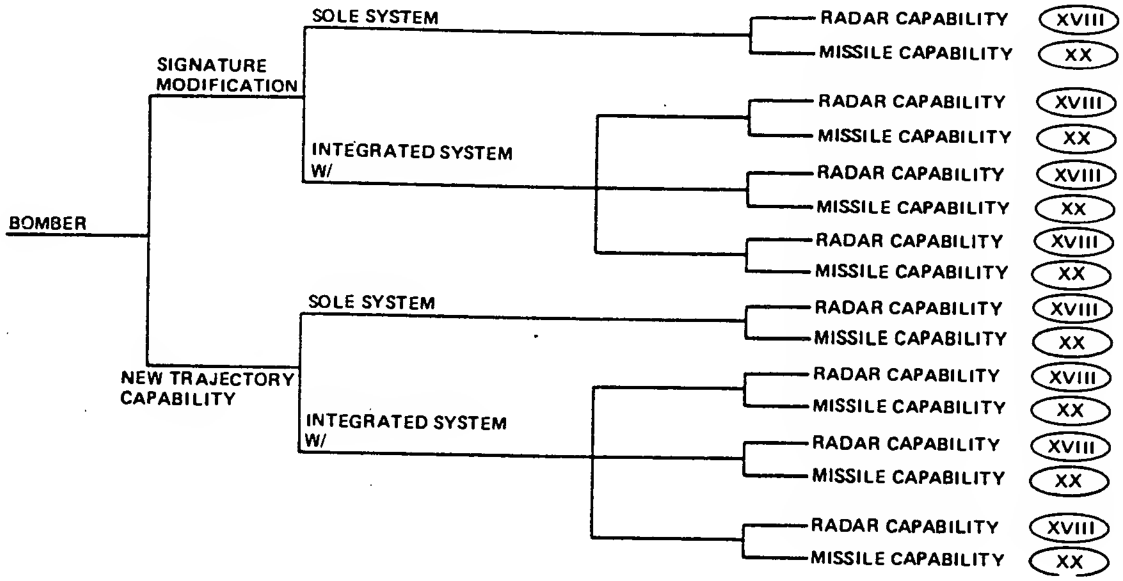
HUGHES



38098-18 (7-21-83)

XIII. BOMBER

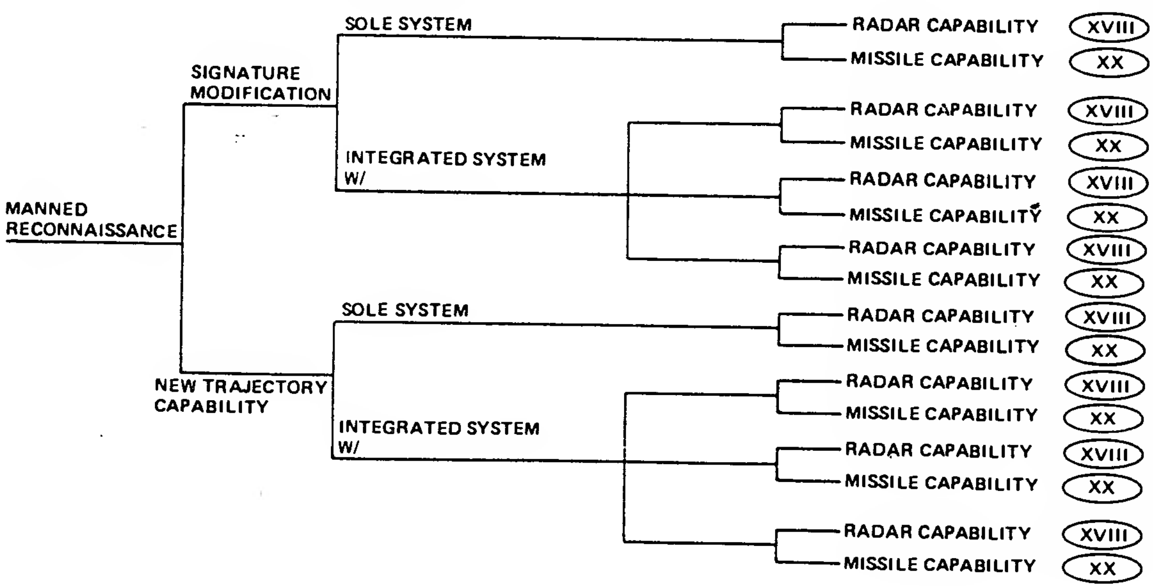
HUGHES



38098-19 (7-21-83)

XIV. MANNED RECONNAISSANCE

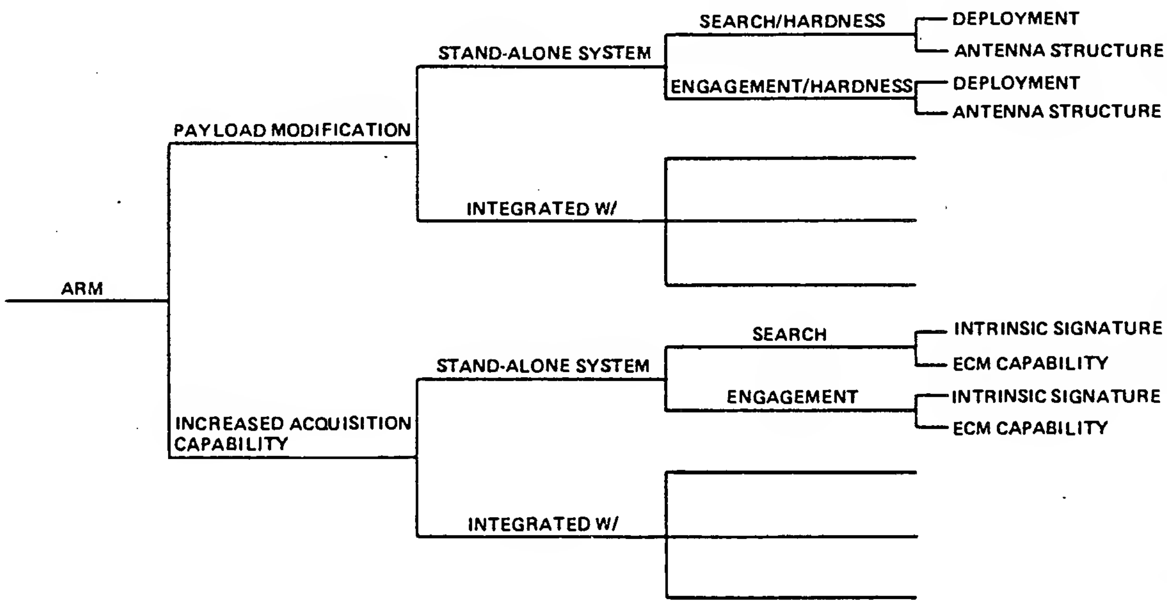
HUGHES



38098-20 (7-21-83)

XV. HARD COUNTERS — ARM

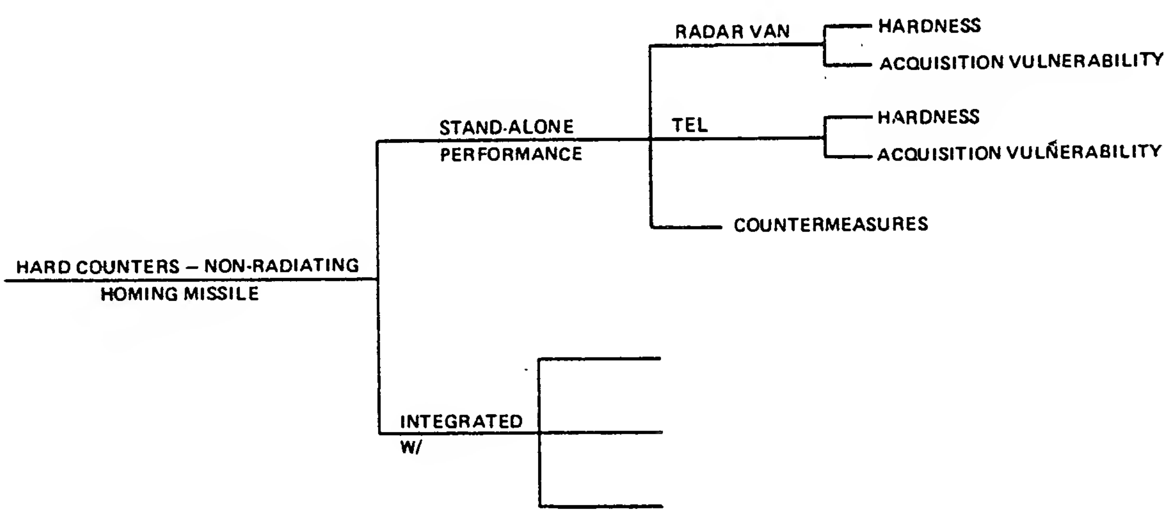
HUGHES



38098-21 (7-21-83)

XVI. HARD COUNTERS — NON-RADIATING HOMING MISSILE

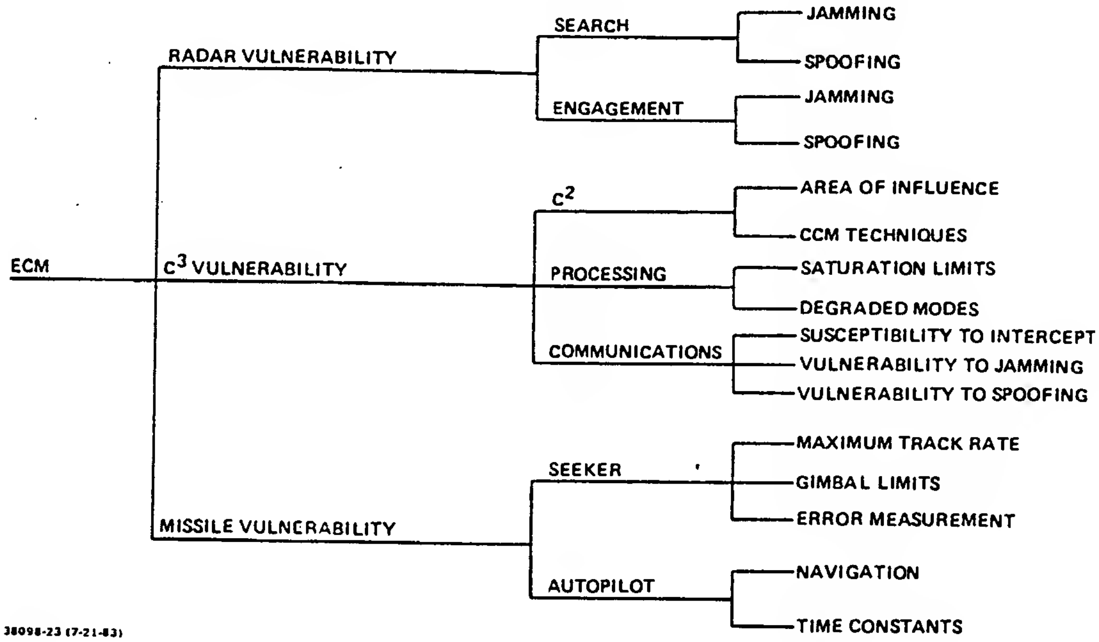
HUGHES



38098-22 (7-21-83)

XVII. SOFT COUNTERS — ECM

HUGHES



38098-23 (7-21-83)

XVIII. RADAR CAPABILITY (SOLE PERFORMANCE)

HUGHES

- RADAR CAPABILITY
  - SEARCH (XXI)
    - LOW ALTITUDE CAPABILITY
    - DETECTION RANGE
    - REACTION TIME
    - NUMBER OF TARGETS
  - ENGAGEMENT (XXI)
    - LOW ALTITUDE CAPABILITY
    - DETECTION RANGE
    - REACTION TIME
    - NUMBER OF TARGETS
    - SEARCH/REACQUIRE MODE

38098-24 (7-21-83)

XIX. C^3 CAPABILITY (SOLE PERFORMANCE)

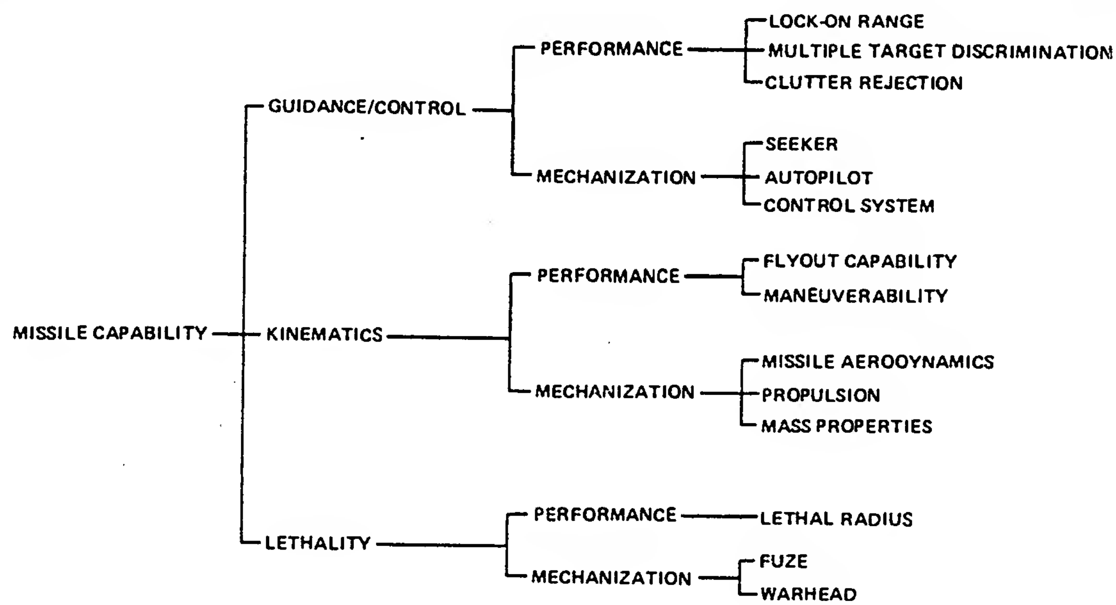
HUGHES

- C^3 CAPABILITY
  - C^2
    - DOCTRINE
      - PERSONALITIES
      - TRAINING
    - SUBORDINATION
      - PERSONALITIES
      - EQUIPMENT
      - TRAINING
    - AREA OF INTEREST
      - PERSONALITIES
      - DEPLOYMENT
    - AREA OF INFLUENCE
      - PERSONALITIES
      - EQUIPMENT
  - PROCESSING
    - DEGREE OF AUTOMATION
      - EQUIPMENT
      - TRAINING
    - LIMITS AND CAPABILITIES
      - EQUIPMENT
      - MAINTENANCE
    - ACCURACIES
      - TRAINING
      - EQUIPMENT
  - COMMUNICATION
    - MEDIUM
      - LINE OF SIGHT
      - LAND LINE
      - TROPHOSPHERIC
    - TRANSMISSION RATE/CAPACITY
    - RANGE
      - POWER
      - SENSOR SENSITIVITY
    - SUSCEPTIBILITY
      - CRYPTOGRAPHY
      - MEDIUM

38098-25 (7-21-83)

XX. MISSILE CAPABILITY

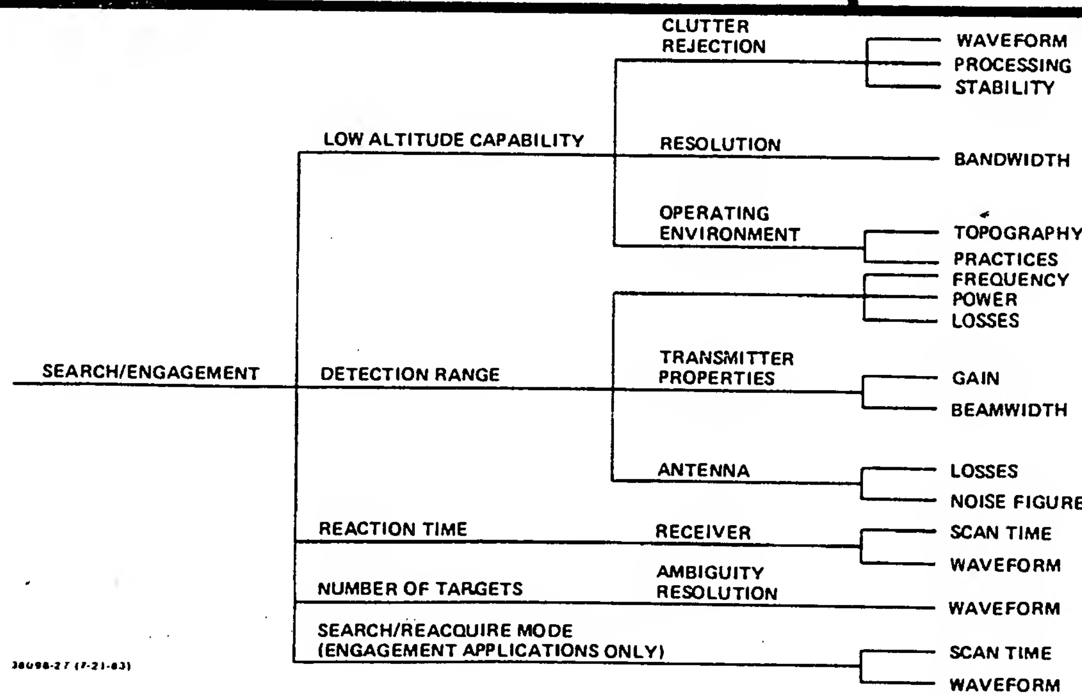
HUGHES



38098-26 (7-21-83)

XXI. SEARCH/ENGAGEMENT RADAR

HUGHES



38098-27 (7-21-83)

V. SUMMARY

SUMMARY

HUGHES

THE METHODOLOGY DEVELOPED AND DOCUMENTED HAS THE FOLLOWING STRENGTHS

- ADAPTABLE
- TRACEABLE
- USES MULTIPLE SOURCES AND TYPES OF DATA
- REFLECTS DECISION MAKERS POINT OF VIEW FOR AUDIT AND REVIEW
- ALLOWS FOR EXPERT OPINION AGGREGATION
- SENSITIVITY ANALYSIS

The major product of this interim report is the methodology which has been developed to perform collection concept analyses. The methodology has been shown to be adaptable to a wide range of problems, is easily used to track the analysis path, and is able to make use of many types of data. The method handles both quantitative and quantitative data as well as allowing for several experts opinions to be aggregated to form a consensus opinion. Most importantly, the method allows for sensitivity analysis which provides for critical review between choices as well as determination of confidence levels in the conclusions reached.

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